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Methodologies Employed to Cool Photovoltaic Modules for Enhancing Efficiency: A Review

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ABSTRACT

Photovoltaic cells are one of the renewable energy sources that have been employed to produce electrical energy from solar radiation falling on them, but not all incident radiate will produce electrical energy, part of those radiate cause the panel temperature to rise, reducing its efficiency and its operational life, unless an attempt is made to employ one of the traditional cooling methods or innovating other methods to cooling it to reduce this effect, which it represented in the active and passive cooling method. In fact, it is difficult to compare the active method with the passive method, as each method has its Advantages and disadvantages that may suit one region without another. But in general, there are basic factors through which at least a comparison between the two methods can be made. Relatively the passive method is less expensive, in addition to no need for additional parts such as pumps and controllers, there is no energy consumption because it does not require power. But it is less effective and efficient than the active method, while the active method has the ability to disperse the heat higher than the passive method. However, it necessitates the use of electricity and is frequently costlier than the passive strategy. In this review, the most common active and passive cases were reviewed, and the pros and cons of each case are summarized in discussion due to the difficulty to list them. The review recommends that future studies should focus on active water cooling and heat-sink, both of which are viable cooling strategies.

1. Introduction

Your Growing world electricity use and rising fossil fuel costs as well as polluting environmental effects have re-encouraged global warming to move quickly into renewable energy, particularly in past few decades [1]. The application of photovoltaic (PV) technologies that convert sunlight into electricity[2] is among renewable energy suppliers' most frequent strategies. This kind of renewable energy technologies reduce global warming problems, pollution free, and reduce operating costs as well as offer minimal maintenance and maximum energy density comparing with other renewable technologies[3]. Solar or PV cells consist of semiconductor materials that directly transform the sunshine into DC electric. When sunlight struck the cells, it releases electrons inside the materials, so that the direct current is produced (DC). Despite considerable advances in technology that convert sunlight into power, the major impediments to the mainstream usage of solar technologies are expensive capital prices and low conversion skills [4]. Aside from the panel's future cost-effectiveness, in comparing to other alternative energy sources, solar power is far more accessible (see Table 1).

A further advantage of PV panels is that they do not have moving components that means that they may easily be maintained while operating smoothly and noiselessly. In addition, solar energy is used in applications such as refrigeration, heating as well

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as desalination [5][6]. The particular solar energy for electricity generation can be selected depending on the desired region's capacity and environment. In 2017, the solar power share exceeded other technology kinds installed, as illustrated in Figure 1.

Table 1. Renewable Energies Theoretical Potential [7]

Renewable Source	Annual flux (EJ/year)
Hydro - power	147
Geothermal	1400
Bio	1548
Wind	6000
Ocean	7400
Solar	3,900,000

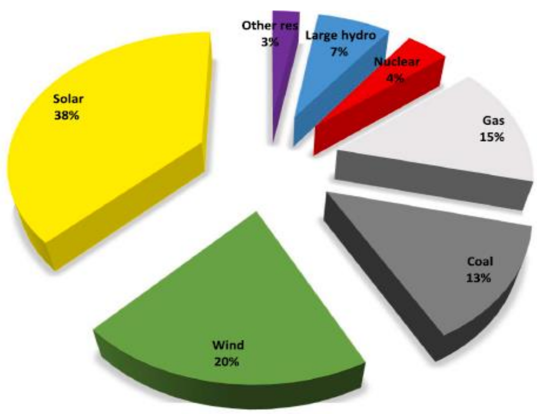

Figure 1. Capacity to generate net electricity using various techniques in 2017 [8].

To meet the aims of this study, a large number of research papers were utilized by various authors. To improve information and to provide effective and easy presentation, many techniques (schemes, images, tables as well as figures) are employed[9].

2. Factors That Influence Photovoltaic Cell Effectiveness

There are general difficulties with this conversion system, including such rain, dust ,and operating temperature that may adversely influence the effectiveness of the generation systems [10]. Exogenous environmental conditions, including wind speeds, are the most common natural components affecting the surface temperature of the PV Module, air temperature, humidity levels, acquired dust as well as solar radiation. Research has shown that the PV panels will improve their productivity by decreasing their temperatures[11]. A change in performance is inicated by the percentage of the temperature coefficient, which increases or falls under normal conditions of 25°C. The panel's temperatures nonetheless approach a top of 70°C in the sunny days of the Equator Region.

Every 1°C raise in the PV module surface temperature results in a performance drop of ~0.45% (temperature coefficient) [12]. PV modules absorb 80% of solar light incoming, however, they do not completely transform it into electricity. The temperature increasing in the Photovoltaic system causes a massive drop in voltage as well as a slight rise in current, which reduces the electricity produced by PV. Thus, panel temperatures higher than 25°C results in electricity degradation performance [13]. In optimum working conditions, the transformation efficiency of single-joint solar panels ranges from 6% to 25%; depending on the materials utilized for the semiconductor preparation of the solar cell [14]. The performance of the solar modules deployed in outside areas is affected by many aspects. Low irradiance effects, dust collection, and high operating temperatures on PV panels have the potential to reduce photovoltaic thermal efficiency and technological lifetime[15]. The efficiency of PV cells fell as intrinsic carrier levels was increased at greater temperatures, which tended to increase the dark saturation current in the p-n connection [16]. Reducing the bandgap owing to substantial doping also raises the carrier's intrinsic concentration. The growth in panel temperature over 25 °C, Voc is declining significantly but the current short circuit, Isc only increases slightly. The combined impact of increased irradiance and temperature causes the panel to be overheated, which could lead to:

- The decrease in performance.
- Low conversion effectiveness
- accelerate the rate of cell breakdown
- Decrease the cell's lifetime.

3. Classification of Cooling Technologies

The proper cooling of the PV array significantly reduces output loss while also increasing the PV module's efficiency. Active cooling necessitates the use of a coolant, such as air or water, it usually requires fans or pumps but which does not require passive cooling to utilize additional power to cool photovoltaic panels [11]. Comprehensive researches on using liquid coolant, air, and other liquids, most commonly water, was conducted in order to manage and sustain the working temperature. A key economic element is whether or not improving power generation through active cooling compensates for electricity usage. Passive cooling might involve additional elements, like a heat pipe, to maintain overall heat flow from the panel to the surrounding environment[17]. Passive cooling technologies are important in reducing temperature PV cells since electricity production is directly from the sun and cost-effective. Fig. 2 shows the flow chart of cooling techniques classification

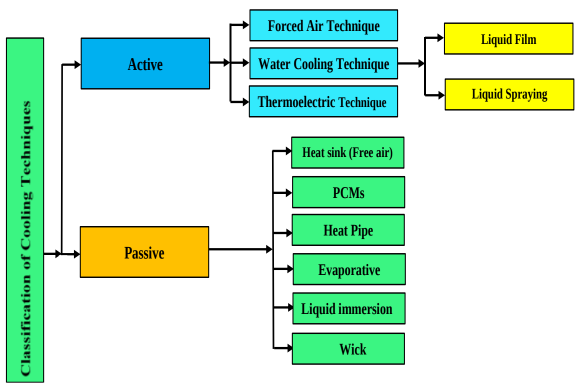

Figure 2. Shows the flow chart of cooling techniques classification in this review

3.1. Active Cooling

3.1.1. *Forced Air technique*

The usage of air in the cooling is popular and beneficial for thermal purposes. The forced air systems are similarly to those for free air [18]. The key difference is that the fan drives airflow through the heat transfer area. This allows increased heat exchange rates, better waste heat utilize and lower environmental dependence [8]. For the purposes of thermal management and temperature decrease, air refrigeration systems are typically used in various devices. While the use of air as a coolant is not as effective as fluids, this approach is still being developed and researchers achieve the maximum heat exchange convection coefficient with air cooling. This strategy is one of the most successful strategies for cooling solar cells by decreasing photovoltaic temperature for increased electric efficiency via forced convection air movement [8]. As have seen in Fig. 3, the device comprises a photovoltaic panel mounted on top of a steel plate via an air channel underneath. Air is employed as the heat exchanger forced by a dust-fan through the channels. The fan is driven by the PV, which raises its energy consumption by an increasing of cavity speed and by increase in channel width as well as the heat exchange surface. The heat is transmitted through the conduits from the PV panel via the air, which reduces the operating temperature change so that electric efficiencies are increased [19].

Figure 3. Shows the forced convection air cooling [19].

In comparison to the cooling cell, the experimental findings indicated a 2% gain in efficiency. The investigation revealed that fan capacity is controlled and managed to increase the efficiency and achievement of the PV panel as little as possible [20]. As air passes through the cell, the cell's temperature decreases by 11 percent as air passes past the cell's forehead, the findings demonstrate a 10% decrease in cell temperature. The cell efficiency (η) improvement rate is 3.7%. And the advantages of this approach allow for easy and cost-effective air use of minimum materials and low running costs.

3.1.2. *Water Cooling Technique*

The cool photovoltaic liquid film or spray technology applies direct deposit to the cell surface front or backside. Due to its availability and thermo-physical qualities, water is frequently employed. The process is suitable for photovoltaic without concentration, in which the area of the cells is proportionate similarly to the heat flux. Apart from cooling, extra pumping power and bulkier procedures are also required. Every one of these technologies can use active cooling technologies to operate a water circulation by using solar-powered DC pumps. In fact, much active cooling technologies has been studied and many practical ways with essential features in this section have been offered [21].

3.1.3. *Liquid Film*

Another efficient approach to refrigerate forced convection caused by fluid circulation through ducts put at the rear of PV panels (water or another kinds of liquid) waste heat for PV Module may subsequently be transported and even employed for other uses due to excess radiation absorption into the circulating coolant[22]. The researcher is comparing the temperatures in the studied modes, which include no cooling and water cooling. This technique has demonstrated its effectiveness for cooling PVs as seen in Fig. 4 [23].

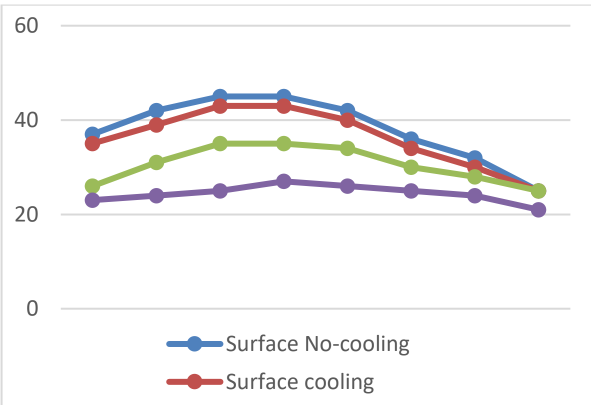

Figure 4. Shows the impact of water cooling on the cell temperature [23].

Depending on the outcomes, active cooling water for PV modules could decrease the temperature of the module by around, 20% that means the efficiency increases by roughly 9%. Apart from improving the electrical efficiency of PV, this technology can also make use of heat extracted for various uses, which means increasing the energy gathered. Wash cells and decreases optical effectiveness reflection and excellent for reusing thermal energy and warm water. Moreover, it can be utilized in the agricultural sector for the watering of agricultural crops. As well as channel shapes, the degree of reduced temperature at PV panels with a liquid cooling approach can be affected by additional factors, such coolant kind [24]. The integration of the cooling system into thermal or infrastructure projects will be workable or irrigation systems in future. Thus according to research [25], the overall achievement of the device is heavily influenced by the heat transmission capacity of the pipe material.

3.1.4. *Liquid spraying*

Liquid sprayed photovoltaic systems cooled by using a trickling spray straight to the front/back of the cell surface. Interesting findings have been achieved from previous study on water spraying, which showed an increment of electrical efficiency in adverse weather conditions up to 15% [21]. Although this system utilizes and disposes of a huge amount of water installed on the terrestrial PV system, the solution for floating solar systems is suitable and cost-efficient. The consequence of the spraying of water on both sides of the panel of Photovoltaic[26] has been scientifically assessed. The findings have shown that the front cooling performance is superior to the rear cooling. The increase in electricity achieved was about 14.6%. To build cool solar panels, a water spray approach was developed [27]. Besides refrigeration, liquid improves optical efficient cleaning of the cell's surface.

Photovoltaic cleaning of PV panels' surface results in better energy production performance[28].With liquid spray, the PV surface may be cleaned concurrently and the temperature difference of a cell can be reduced. In research[29], the nozzles were developed to spray liquid at the top of a PV panel and can be seen in Figure 5. The heat dissipation system was utilized in this arrangement to automatically control the panel's temperature by means of his rear side. In addition, this mechanism is used to control the washing of the front surface. The cooled panel's efficiency and temperature were compared with the corresponding PV with the same dimensions but no cooling system. With the employment of the nozzle for water sprays, the temperature was lowered because to evaporation on the PV-surface. The panel with the proposed cooling system had the greatest generated power of 89.4 W, whereas that number was 68.4 W in the reference instance. Furthermore, the performance for cleaned as well as cooled panels was 11.7%, but for PV without a cooling system the comparable number was 9%, significant results are shown in the research of active thermal control of PV cells [8]. The solar array temperature drops to 35 °C by using a water spray.

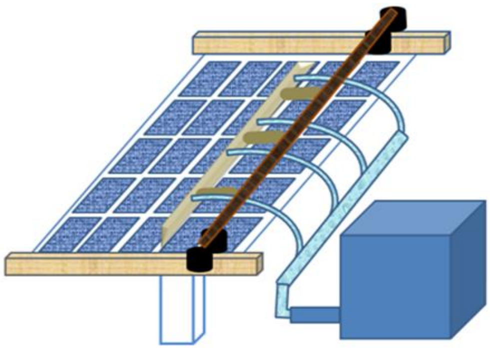

Figure 5. Shows the design of cleaning and cooling systems for Photovoltaic panel [30].

3.1.5. *Thermoelectric Technique*

Cooling thermo-electrical (T.E.) is another approach utilized to reduce the temperature of the PV panel. n-type semiconductors and p-type semiconductors are coupled electrically in series and thermally in parallel in (T.E) system. The Peltier finding implies that, in the presence of a temperature gradient, the bulk of charging carriers diffuse from the hot side (electrode charged) to the cold (electrode negatively charged), resulting in a voltage that causes current to flow[31]. The Peltier effect is produced by an electric junction with a thermal flow. It heats one side of the junction and cools the other, necessitating the employment of a heat sink to disperse the excessive heat. The heating/cooling flow varies according to the temperature and voltage/current variations [32]. Figure 6 shows the described thermo-electrical cooling system.

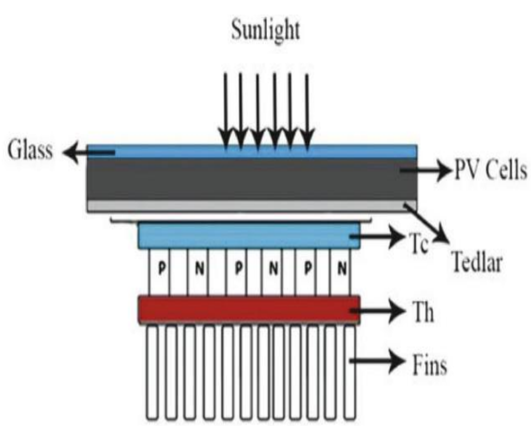

Figure 6. shows the thermo-electrical cooling system [33].

Thermo electrics were utilized for cooling photovoltaic and generating power out of its current temperature gradients. The Photovoltaic cell cooler with a Peltier component was modeled by Najafi and Woodbury[34]. It was proved possible to include thermoelectric cooling for high condensation Photovoltaic cells. Borker et al. experimentally researched the thermo-electrical cooling of a P.V. panel [35]. The findings showed the improving effectiveness of the PV panel from 8.35% to 12.26% to 13.27% owing to T.E. cooling. Benghanem et al.[36] noticed that T.E modules reduced the temperature of PV cells from 83 °C to 65°C. The thermo-electrical system offers the electricity obtained from the panels. Consequently, The T.E. module should consume significantly less electricity than is provided by cooling power panels [33] in order to be dependable.

3.2. Passive Cooling

3.2.1. *Heat Sink (Free Air)*

Heat sinks are one of the strategies of cooling that use a metal with high thermal conductivity. To dissipate heat from the solar cell as shows in Fig.7, the operation variation in PV module temperature was investigated experimentally without and with an active cooling system in order to determine the PV module's electrical performance. As shows in Fig.8, this test used two multi-crystal silicon solar modules with a peak efficiency of 13% under typical conditions (25°C, 1000 W/m2), one of the modules was utilized as a reference, and the second PV panel was put on the bottom of it with an aluminum heat sink with a DC brushless fan. The temperature of PV modules without and with cooling systems was 30% and 70% respectively is higher than the ambient temperature. As a result, the PV module with cooling system had a slightly higher open circuit voltage (Voc) than the PV module without a cooling system [37]. Using alternative designs of a ribbed wall heat sink, the drop in temperature of the PV panels was also examined numerically during a clear day in July at air passive a a cooling. wherein found that the panel's maximum temperature at the angle 45° was less than from that at the angle 135°, the study also discovered that when we use a heat sink, even for small heights of the ribs, the average temperature of the PV panel is reduced while the maximum produced power by PV panel increases by 6.97 percent and 7.55 percent, respectively, compared to the reference case, at ribs angles 90° and 45°, respectively, resulting in a temperature reduction of at least 10 degrees [38]. This cooling method for PV panels is commonly used because of its dependability, low cost, and simplicity.

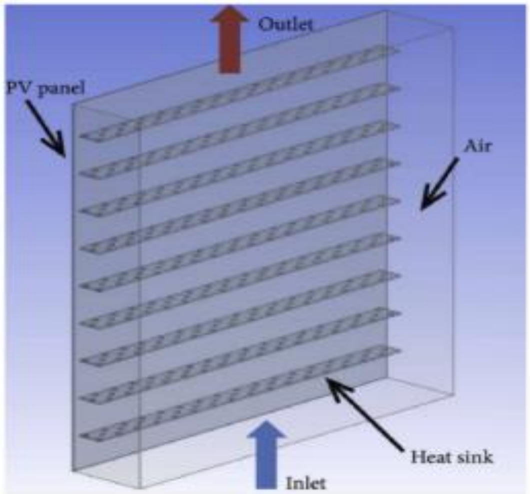

Figure 7. shows PV module Back side for Heat sink[38].

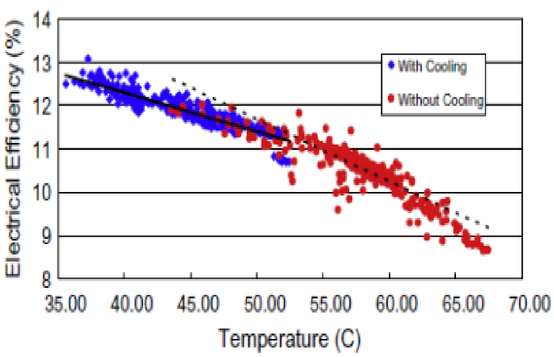

Figure 8. Electrical efficiency as a function of PV temperature for Heat sink [39].

3.2.2. *Phase Change Materials (PCMs)*

The method of cooling solar cells using phase change materials is one of the methods of cooling by the passive cooling method, and by reviewing the studies on cooling of this type we see that many types of these materials have been employed and in methods that differ from one researcher to another that ultimately led to improvement efficiency of the panel from lowering the temperature, wherein capable to improve the ηEl of the PV module up to 5%. By this cooling method, the TPV of module can be maintained between 25°C and 30°C [40]. PCMs cooling is a passive conductive cooling method that uses phase change materials. It works in the same way as a thermal battery rechargeable [41]. They are substances with substantial latent heat capacities that can store and release significant thermal energy amounts virtually isothermally. The performance of phase change materials is heavily influenced by static material properties as well as the surrounding environment [42]. Into phase change materials can cool solar cells by absorbing and releasing the heat (melting) during the day and (solidifying) in the evenings this heat could also be used for other reasons, for example, space or water heating Building-integrated thermal systems and photovoltaic thermal systems benefit from phase change materials. This is because of their ability to store and release significant amounts of thermal energy over long periods of time. PCMs can store around 33% more heat and increase their availability by 75–100% when in comparison to water photovoltaic-thermal systems [43]. The thermal conductivities of phase change materials are low, limiting cooling speeds and temperature homogeneity, thus we can increase the thermal conductivity of these materials by increasing the surface area and this is done through the use of fins, but this leads to an increase in the cost of the system. Phase transition materials are now commercially unviable due to unreliable performance and expensive costs. Microencapsulation [44], salt hydrates, compression expanded natural graphite[45], and material segmentation is some of the newer research fields. According to numerous researches, organic hydrocarbons' structure has a poor thermal conductivity, which reduces rate of charging and discharging heat during the melting and solidification cycles. Inorganic PCMs, on the other hand, have a larger phase transition enthalpy, resulting in characteristics that improve thermal performance the temperature and cooling of PV panels can be controlled using a specific PCM, the CaCl26H2O – Fe3Cl26H2O eutectic[41].

3.2.3. *Heat Pipe-Based Photovoltaic System*

Heat pipes are efficient heat transporters that integrate both thermal conductivity and phase transition principles. Evaporator, adiabatic, and condenser portions are the three sections of a conventional heat pipe. The liquid working fluid inside the wick in the evaporator section is vaporized by the heat input. The vapor moves towards the colder condenser section, bearing the latent heat of vaporization. The vapor condenses in the condenser and releases its latent heat. By capillary action, the condensed liquid returns to the evaporator through the wick structure. As long as the temperature gradients between the evaporator and condenser are maintained, phase change processes and two-phase flow circulation persist[46]. The heat pipe consistingof one end serving as a collector of the thermal energy and the other as a dissipator of the thermal energy, are an ideal solution to removal and transport of the heat [47]. To cool the rear of the solar cells, a passive cooling solution was used with two heat exchangers piped together and charged with refrigerant type R-11[47]. A heat pipe was used to cool a 1 cm2 PV cell that was lit with 40 W/cm2 waste heat. The maximum temperature differential between the cell and the surrounding air was 43 °C [46].

A heat pipe was also employed to cool a 0.0625 m2 PV panel. The gain in efficiency was measured in absolute terms. At maximum illumination, the efficiency increased by 2.6 percent and the temperature dropped by 4.7 degrees Celsius. The highest improvement in electricity yield was 8.4%. In this instance, the heat pipe size must be considered. The cell's size is about the same as the heat pipe's size [41]. It's debatable whether this form of cooling should be utilized on large-scale models, but can be done easily on the PV cells concentrated, as recommended in[46].

3.2.4. *Evaporative*

Evaporative cooling systems generally employing the water's latent heat of vaporization to dissipate significant amounts of thermal energy passively [64]. The evaporative cooling method is most practical beneficial and high-potential method of controlling the temperature of PV panels [77]. Considered the porous foils [78] clay [79] and cotton wick structures [77] as a typically evaporation surfaces. The simplicity of it surface make its preferred especially with free air systems, also there are factors that make evaporative cooling method preferred such as the hot weather, dry and a plentiful of water [31]. The evaporative cooling approach was investigated and a 6C◦ reduction in PV panel temperature was observed in spite of this decrease in PV surface temperature isn't huge but can be increased and the cooling process can be improved too [81]. In the clay pot, the impact of evaporative cooling water was investigated and found the temperature of the pot water is always 5-8 degrees Celsius lower than that of the surrounding air [82]. The impact of evaporative cooling on PV module efficiency was investigated wherein a layer of synthetic clay was applied to the rear of the module and notice a thin film of water was evaporating, led to increase of 19.4% in output voltage and 19.1% in output power [79].

3.2.5. *Liquid Immersion*

Liquid immersion is the process of partially or completely immersing photovoltaic cells in a liquid that is either stationary or flowing. The liquid has better thermal physical qualities than air, allowing it to maintain the temperatures lower and more stable. The liquid also helps to prevent reflective losses and grime build-up. In towns with limited space, being near bodies of water may be useful. Corrosion, leakage, and salt deposition are all challenges for the practical deployment of cells over time[48]. Immersion in or in contact with, phase transition materials can be used to cool higher solar concentrations [49]. Additional information on immersion can be found in [50]. A variety of cooling fluids were compared. Isolation liquid, de-ionized water, and three distinct organic liquids are used in the immersion. The kinship increasing in efficiency is up to 15%. A number of factors must be considered. The small cell in comparison to liquid amount and its casing considered as a main reason in addition to the height solar concentration which it reaches to 30 suns necessitates a significant quantity of cooling, which it assumes accomplishing with passive liquid cooling. Temperature measurements should be taken for a better understanding, which is not done in [51].

3.2.6. *Wick Structure*

Thermal management with liquids such as water helps to remain the cell at a lower temperature. A capillary structure can be used to provide this cooling fluid passively. It has been developed a thermal management passive system that uses heat spreaders in conjunction with cotton wick. The maximum temperature of the PV module was reduced by nearly 12% from 49.2°C to 43.3°C. This is accomplished by a combination of evaporative cooling and effect of fins heat spreaders on the PV module's backside. As the temperature of the PV system drops [52]. The electrical output was increased by 14%. Cotton wick was also used at the rear of a PV panel as shown in Fig.9 to create capillary force for the cooling working fluids. here are three distinct coolants had been used, which were water, Al_2O_3/water, CuO/water, and according to their findings the employing of aforementioned fluids reduced the temperature of panel by approximately 30%, 1%, and 11% respectively compared to no cooling. The wick's moisture content which was driven by capillary action given by way of wick was blamed for the PV module's lower temperature. The adherence of nanostructures to the wick structure, which worsened the capillary action was blamed for lower temperature reductions in the circumstances of utilizing nanofluids [53].

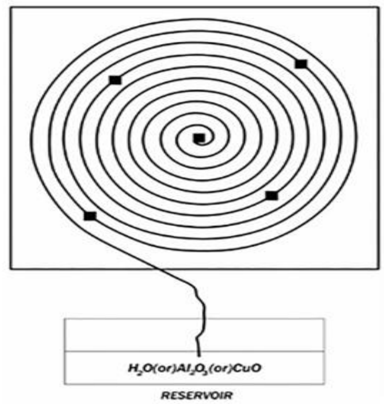

Figure 9. Wick thermal structure [53].

4. Discussion

An extensive review of the cooling approaches was carried out depending on the system kind used to decrease the temperature, consequently, it is vitally essential that the results achieved are described and clarified. As is common, there are two main methods of cooling, the active method, and the passive method, and as shown in Table (2), Active and Passive Refrigeration Systems from which sub-methods are employed for the desired goal, which is to cool the photovoltaic cells. passive method: Pro-duction and upkeep are less expensive. There is no active control, as well as much lower maintenance, is There are no parasitic losses because it does not require power to run, reducing net energy production. otherwise, the Active method has The ability to disperse higher heat exchanges. Waste heat harvest: de-sign of fluid pumping (fan, pipes, as well as a pump) makes it easy to use otherwise squandered heat energy. For a particular heat removal efficiency, more compact packaging is available.

Table 2. The Basic General Benefits of Active and Passive Refrigeration Systems

Passive	Active
Production and upkeep are less expensive, parts such as pumps and controllers are missing.	Heat dissipation: The ability to disperse higher heat exchanges.
Dependability: There is no active control and much lower maintenance. May electricity generation be delayed.	design of fluid pumping (Controls, fan, pipes, and pump) makes it easy to use otherwise squandered heat energy.
There are no parasitic losses because it does not require power to run, reducing net energy production.	Compact: For a particular heat removal efficiency,

Table (3) shows The Key Benefits and Cons of Every Cooling Method System, which includes a summary of the benefits and determinants of using each type. Active method (Forced-air circulation) Higher rates of heat transfer, do not depend on ambient conditions, are economically viable, and the overall efficiency is high. Limitations Higher costs, Potential for air-limited heat exchange, and Potential problems in dust accumulation Consume enormous quantities. (Liquid film or spray) Simple process and very effi-cient, an Improved process of heat transfers than nat-ural ventilation, and Excellent for reusing thermal energy and warm water. Limitations Need a substan-tial amount of surface area, installation and mainte-nance costs are high, and The heat that is withdrawn cannot be properly stored for subsequent usage. (Thermoelectric cooling) Temperature regulation that is accurate and sensitive, Reversible performance: heat and electrical, Low maintenance cost, no moving parts, no noise issues, small size, Limitations Low thermal transfer capability, Heat transfer depends on ambient conditions, Dust deposition on ducts.

Table 3. The Key Benefits and Cons for Every Cooling Method System

Cooling	Techniques	Strength	Limitations
Active	Forced-air circulation	• Higher rates of heat transfer • Do not depend on ambient conditions • Potential thermal energy recovery, warm air	• Higher servicing and costs compared free air systems • Potential for air-limited heat exchange • The extracted heat cannot be achieved optimal

	Liquid film or spray	• Wash cells and decreases optical effectiveness reflection • Improved process of heat transfer than natural ventilation • Excellent for reusing thermal energy and warm water.	• Needs a substantial amount of surface area • Installation and maintenance cost are high • The heat that is withdrawn cannot be stored
	Thermoelectric cooling	• Temperature regulation that is accurate and sensitive • Low maintenance cost • no moving parts, No noise issues, small size	• Heat transfer depends on ambient conditions. • Dust deposition on ducts • Poor efficiencies with heightened Electricity consumption
Passive	PCM	• There is no need for maintenance and there are no electrical expenditures. • Can keep PV panel for a long time at a consistent temperature • Heat stored can be effectively	• Inflexible & unreliable operation, depending on the basic material and environmental conditions • Lower thermal conductivity decreases the rate of heat exchange • Rising costs for the system
	Heat pipe	• Excellent longitudinal heat transfer capabilities. • Easy to implement, passive relatively cheap heat exchange.	• Heat transfer rates are poor • a buildup of dust on the intake grate • influenced by wind conditions
	Free air	• Operations is easy, low-cost, extremely reliable, as well as noise free.	• Low heat transfer rates, which are influenced by the heat transfer area and surrounding atmosphere. • Possibility of dust accumulation
	Liquid immersion	• Larger heat dissipation • Better electrical performance • Heat transmission rates that are moderate • Minimize ophthalmic losses due to reflection	• problem of Ionization of water • Corrosion may occur so appropriate care is required • Containment design and its weight • Floating system requires water body.
	Evaporation	• Passive functioning leads to high thermal transfer efficiency.	• Take up a considerable amount of surface area • Limitations in distribute water • There is no recycling of water.
	Wick structure	• Moderate heat transfer rates • Better electrical performance • Noiseless operation	• Require large surface areas • Water is not recycled • Liquid may be ingress due to leakage

Table (4) included each method and the amount of improvement in electrical energy efficiency in exchange for the amount of temperature reduction in solar panel temperature. It should also be noted that it is difficult to make a comparison and conduct a feasibility study in general between the passive and the active method or to give precedence to one over the other unless the comparison is limited because each method suits one case without the other.

Table 4. The Comparison Of The Methods Used

Researchers	Type of cooling system	Specifications and electrical efficiency	Temperature & efficiency achieved
Teo et al [11]	Air cooling (Active)	4 panels, 55 Watt polycrystalline.	38°C
Moharram et al. [27]		Desert zones Photovoltaic Monocrystalline-silicon modules (Egypt)	By using the cooling system for 5 minutes, efficiency 12.5 percent could be boosted
Teo et al [11]	Air cooling (Passive)	4, 55 Watt polycrystalline solar Panels	68°C
Krauter [54]	Water spraying	Six-single as well as multicrystalline 55 W rated energy silicon solar panels. 2 L water per minute at the top of the modules with 12 nozzles.	38°C
Kane et al. [55]	Thermoelectric	G = 1000 W/m2 with Temp of 25°C, 35°C, and 45°C	40°C at 25°C 46°C at 35°C 52.5°C at 45°C
Firoozzadeh et al. [56]	Heat sink	This increases efficiency to 2.72 %.	Temperature decrease up to 7.4 °C

Arifin et al. [57]		raised (VOC) as well as (MPP) by 10% and 18.67%	Temperature decrease from 85.3 °C to 72.8 °C
Hasan et al.[58]	PCMs	PCM 1: eutectic mixture of capric-palmitic acid	40°C with PCM 1 in (Dublin)
Yang et al .[59]		The improvement in electricity efficiency from 6.98% to 8.16% by adding PCM to the PV/T system.	-
Tang et al. [41] Habeeb et al. [60].	Heat pipe array Thermosyhon Heat pipe	The consumption of power increased by 8.4% and 13.9% 11–14% increase	4.7 °C reduction: Air cooling 8 °C: water cooling. Decrease of 15–35%.
Alami [61] Lucas et al. [62]	Evaporative evaporative chimney	15% improvement in energy output An average rise of 4.9–7.9 percent in electricity generation.	High panel reference temperature (85 °C) The decrease in temperature was above 8 °C
Mehrotra et al.[63]. Pushpendu Dwivedi [21]	Liquid Immersion	2 W polycrystalline solar silicon panel plunged into different water depths	31-39°C 40 °C
Chandrasekar et al. [53]	wick	Electrical efficiency improvement by 15.5% (with water) Al2O3/water, as well as CuO/water nano-fluids)	45°C - 20°C decrease in temperature

5. Challenges and Future Work

The following is a list of the challenges of designing an economical PV cooling system. The necessity to identify and understand the several variables that influence the cell temperature and the effects on prospective cooling systems. Depending on several parameters including modules direction, positioning, and cooling elements, design systems are necessary.

- Large surface area to cool with a very low output per unit due regard.
- Assure a uniform distribution of temperatures from across the working area, as the hotspot raises the modular degradation.
- Balancing the higher initial expenditure with higher results. An effective refrigeration system should therefore be particularly cost-effective because it doesn't really enhance the system costs significantly.
- Although there are no test standards, there are various metrics and variables to measure the efficacy of P.V. cooling systems.

6. CONCLUISON

This research includes an exhaustive literature assessment of the many cooling technologies used to refrigerate photovoltaic cells. Solar PV cells have a number of factors affecting their effectiveness, including the material utilized, the surrounding environment, and the operating temperature. One of the parameters that have a considerable influence on the operation of the cell is temperature, which should be kept as low as possible. This study compares the most efficacy PV cooling technologies in the hopes of gaining a better understanding of cooling strategies in photovoltaic systems' design, implementation, and future development. The following are some of the most important conclusions from the examination of several PV cooling systems.

The following is a summary of the various cooling techniques that are commonly employed to cool the solar cell, which was compiled by analyzing a range of recent studies and literature on this subject.

- The basic advantage of passive cooling technology is its autonomy and the fact that they do not necessitate any additional power usage while maintaining a simple design
- Active cooling systems are capable of providing high-performance heat transfer and better cooling rates of PV cooling, but heat dissipation rate and its amount remain the main problem.
- Liquid spraying is also an active method of cooling the cell that makes use of the liquid's latent heat, as well as contributing to the cell's increased energy output by cleaning the cell surface of dust and debris.
- Ambient air conditions as well as the type phase change material (PCMs) used have a big impact

on the viability of using (PCMs) for thermal control.

- The adhesion to the wick structure of nanostructures impeded the capillary action, which led to reductions of heat transfer when utilizing nanofluids.
- As a result, the power consumption of thermoelectric modules should be substantially lower than the P.V cooling energy to be reliable panels.

A simple and cost-effective solution is hard to find the method that can solve all problems because each was created in response to different situations due to a lack of data on economic performance. Future research could depend on financial analysis and its effects on the environment. The fundamental goal of future technological progress should be to develop hybrid cooling technologies with the primary goal of keeping the surface temperature low and steady. Upcoming studies should focus either on active water cooling or on combination heating pipes and heat-sink, which are both viable cooling strategies.

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