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A new method for improving the solar photovoltaic unit efficiency through neem oil as coolant medium for high power applications—an experimental investigation

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Abstract
The utilization of electric energy is rising in the technological world. Solar PV (photovoltaic) cells convert sunlight into electricity, and sunlight radiation also has heat, reducing the panel's efficiency. The heat should control the limited value or otherwise reduce the panel's performance so that heat is moved to the cooling medium, thus maintaining the heat within the functioning limit. The proposed method is explained by the probability of cooling the monocrystalline and polycrystalline structures used as neem oil through an integrated oil container fitted into the unit's backside—the neem oil acts as phase-changing material (PCM). The solar PV rear side neem oil absorbs the heat of the solar PV panel. The neem oil is not filled in the backside tank completely for the reason that the oil needed some breathing gap. The breathing gap of PCM is to enhance the heat-withstand efficiency. The backside neem oil is replaced every 30 min. As an outcome, the front side of solar PV heat is reduced. Neem oil has not polluted the environment and is thus also used to exchange noxious mineral oils. The neem oil moved from the depository tank to the backside of the unit and together into an additional depositor tank, thus being able to be reused. The proposed method is investigated, and functioning comparison occurs in different PV types, such as monocrystalline and polycrystalline modules, with various kinds of edible oil. Thus, the critical outcomes of the monocrystalline and polycrystalline PV panels are to decrease the panel temperature by 2.29% and 4.34%, respectively, and enhance the efficiency of the PV panels by 15.0% and 17.8%, respectively.

Keywords Photovoltaic/thermal · PV cooling · Efficiency · Neem oil · Output power

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Abbreviations

T	Time
G	Solar irradiation
T_a	Ambient temperature
M_{MT}	Monocrystalline module temperature
P	Output power
P_{MT}	Polycrystalline module temperature
Pm	Maximum power
Vmp	Voltage at maximum power
Imp	Current at maximum power
Voc	Open circuit voltage
Isc	Short circuit current

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1 Introduction

In the sunlight of able-to-be-seen wavelength, the upper limit is 1200 nm, and the lower limit is 400 nm, immersed with the solar panel and transformed into electrical energy. The occurrence of solar light also generates heat that increases the panel temperature. The output efficiency of the panel was decreased. The real-time efficiency of the monocrystalline solar PV is 12–18%, while the lab efficiency is 25% [1, 2]. In ref [3], the novelist experiential to the standard efficiency has monocrystalline and polycrystalline units throughout summer reductions through 20.1% and 19.6%, compared to wintertime. Solar PV absorbs more heat in the summer.

In the very hot and dry area, the functioning heat of PV can amplify up to 81 °C [4], but in the steamy area, amplify further than the functioning limits, thus giving on to thermal deprivation and decreased competence [5]. The deprivation in exchange competence of 0.51% occurs for each 0.9 °C increase [6, 7]. In addition to amplifying functioning heat, partial shading and hot spots influence competence [8–13]. In a series connection, cells have partial shading; thus, cells operate to the load to lose the power as heat. Thus, the problem is overcome by connecting the bypass diode transversely to a series of linked cells [9, 14]. The increasing temperature was controlled by using various cooling methods, such as the warm plug, decreasing efficiency and producing warm air pressure in the ASA compartment, thus dropping the consistency of the arrangement [9]. Consequently, the situation is critical to removing the heat of the PV cell. The heat produced in the unit can decrease with wind or liquor cooling materials, such as the frontal exterior. Wind-cooled solar arrangements are based on different and economical resolutions to construct an incorporated arrangement. The wind hole connecting the unit and rooftop can circulate the wind to decrease the heat of the PV unit, and pre-heated wind was able to be used in thermal Construction. [15, 16]. To analyze the construction-incorporated PV arrangement and use the usual wind to reduce the unit's temperature, the temperature and wind-produced force among the apex and base of the space determine the wind run. Likewise, numerous methods, such as fins [17], matrix [18], and crowded wind flow way [19], have been used as a cooling intermediate for the PV element. The reference used was air and liquid acting as coolants.

The two different types of solar PV cooling techniques used in existing systems are solar PV backside cooling and solar front cooling. In Ref [20], front side of water cooling method—considered dropping the indication on the PV unit using a layer (0.9 mm) of operation water on the unit's front exterior—the outcomes amplify the functioning by 10.6% over the day. Ref [21] investigated the PV arrangement's functioning by giving water to the unit's higher exterior. The investigated confirmation is to amplify 16% of efficiency in time-mission circumstances. In Ref [22], better-quality functioning of the solar water drives arrangement with scattering water in excess on the frontage exterior of the unit. The novelist established that spraying aquatic to the frontage exterior decreases the indication and heat of the PV panel. In Ref [23], an analysis of the functions of the unit flooded with water improved the arrangement's efficiency. Together, wind and water can be used as a cold intermediate to move the temperature generated by the unit. On the other hand, the PV arrangement using water as a cold intermediate is more competent than air owing to its high-value thermo-substantial belongings [24].

The mineral oil is a cold intermediate that produces noxious matter owing to oxidative unsteadiness. The tools' method breaks down, and removing inorganic oils remains hard—the outflow of inorganic oils be able to source a severe hazard to the atmosphere. Consequently, silicon oil is used as another mineral oil containing a high-value flash factor; it is more costly and not good for the environment. Hence, vegetable oil can be used as an exchange cooling intermediate for transferables and is thus highly obtainable, inexpensive, renewable, recyclable, and safe. Vegetable oil is a triglyceride extracted from vegetation or the seed and turns fluid at room temperature [25].

In this examination, this inspection used waste oil such as neem oil cast offers the temperature transport liquid to uphold on necessary functioning heat of the unit. Edible oil has benefited concentration due to its accessibility, environment-friendliness, fewer hazards, and small influence on the atmosphere [26]. In other words, different types of PCM are available. Aluminum metal foam (AMF) is used as PCM for thermal transformation [27]. Next, the paraffin wax RT-42 is used as PCM, which is useful to the rear face of solar PV [28]. Dual inorganic salts, sodium carbonate decahydrate (SCD) ($Na_2CO_3.10H_2O$) and magnesium sulfate heptahydrate (MSH) ($MgSO_4.7H_2O$), help the functioning of solar PV by acting as PCM [29]. The various combinations of nanoparticles are active as PCMs with the help of thermal regulation [30]. In the passive cooling methodology, three categories of PCM containers are used: grooved, tubed, and finned. The related incorporated technology cooling method has two categories: active and passive cooling [31]. Various kinds of solar PV cooling techniques are available, and here, three different techniques are used: air, water, and PCM-based. Based on three methods, the PCM-based cooling performance is better [32]. The effectiveness of solar PV superior by using active cooling inorganic PCM ($CaCl_2.6H_2O$–$Fe_3Cl_2.6H_2O$) has a good melting point and a high latent heat of 208,000 J/kg [33]. At the same time, the inorganic mixture combination of sodium sulfate decahydrate ($Na_2SO_4 \cdot 10H_2O$) and zinc nitrate hexahydrate ($N_2O_6Zn \cdot 6H_2O$) PCM was used in the building integrated semi-transparent photovoltaic (BISTPV) [34]. The method of experimental analysis was cooling evaporation and aluminum fins with cotton wicks absorbed in water to enhance solar PV output power by 73% [35]. Next, the zirconium oxide (ZrO_2) nanofluid was circulated with a heat exchanger. The performance of solar PV was analyzed at different concentrations of nanofluid [36]. The performance of dual-axis solar tracking solar PV was superior as compared with stationary solar PV [37]. The three dissimilar cooling methods were used in the comparative analysis like water cooling, fin cooling, and without cooling. The method of water cooling was superior to reducing the panel temperature [38]. The cross-fin channel box was used with different cooling waters. The performance of solar PV was measured by the amount of heat exchange from the panel to the cooling medium [39]. Next, the data analysis was a long-term process. The method was applied to three different climatic conditions [40]. And different kinds of environments also affect the performance of the panel [41]. Vegetables have enhanced thickness, flash factor, and dielectric power and secure flames better than mineral exchange oils (neem oil). Depending on what happens, the final uses of vegetable oils are intimated as neem oil.

From the analysis of various literature studies to find the following problems, solar PV efficiency is decreased by increasing the absorption of heat. Next, cooling techniques are required for an effective selection of materials [42, 43]. The major objective of the proposed technique is to effectively select cooling material (neem oil) to decrease the solar PV panel heat and enhance the efficiency of the method.

According to the literature, heat absorption via increasing temperature affects solar PV's functioning. So, heat was limited with the help of different phase-changing materials (PCMs). One of the phase-changing materials is used as oil. The various kinds of analysis of solar PV functioning are affected by temperature absorption [44, 45]. The different oils and various PCMs perform different functions. The proposed method uses alternate neem oil that acts as a coolant. Because the benefits of neem oil are naturally available, pollution is less, and the viscosity of neem oil is suitable. The goal of the proposed technique is to reduce the solar PV heat and enhance the panel's competence. Here, the proposed method first has a neem oil storage tank that collects the neem oil. The cooling tank is integrated into the solar PV backside. The integrated cooling container is full with neem oil—the neem oil acts as PCM. Because of the PCM, the inclusion of solar PV heat is reduced. It improves the thermal transformation and enhances the performance of the solar system [46, 47]. The backside of neem oil is changed at regular intervals because of the increasing temperature of neem oil. The neem oil is not full in the backside tank completely for the reason that the oil needed some breathing gap. The method has another tank for collecting use, a neem oil storage tank, which collects the used neem oil for a particular time interval.

Moreover, three different valves regulate the system's functioning: the inlet, outlet solenoid valve, and the pressure air control valve. Neem oil has a suitable viscosity, flash point, and dielectric strength and is safer for fire issues than mineral oil. The key assistance of the proposed method are:

- Depending on the physical and chemical features of neem oil, it acts as a coolant, an alternative to mineral oil.
- Neem oil is readily accessible and does not pollute the environment.
- The viscosity of neem oil is suitable, so it enhances the competence of solar PV.
- The disposal of neem oil is easy compared with mineral oil.

The arrangement of the manuscript is prepared as part 2, which explains the investigational unit designed for solar PV system functioning and the cooling preparation. Part 3 explains the outcome, and Part 4 discusses the investigational examination of neem oil and comparative analysis and economic benefits; finally, it moves through a conclusion part. Figure 1 is indicated as a representative diagram of the proposed system.

2 Investigational setup and experimental procedure

The proposed method's construction (Fig. 1) is the solar unit, neem oil storage tank, rear oil tank incorporated through PV unit, force air drive, and used neem oil collected tank. The neem oil storage tank collects and stores used neem oil, which is then reused in solar PV cooling techniques. After the collection of neem oil, the oil is flown to the solar PV backside tank, and the flow is controlled by using an inlet control valve. Then, neem oil is replaced in a particular time interval, and the used neem oil is flown through a used neem oil storage tank. After that, the solar PV oil flow is controlled by using an outlet control valve.

The functioning of the solar unit by way of the purpose of Neem oil cooling is an investigational monocrystalline and polycrystalline unit (17-inch × 14-inch) including and not including cooling part back side oil depositary tank of 16 inches × 13 inches × 1.6. The rating of both panels is 50 W. The investigational setup (Fig. 2) is designed on the rooftop. The solar and temperature indicators calculate the occurrence of sunlight and heat in the PV unit. Together, the units are constructed of an oil-incorporated tank fitted toward the rear of the PV unit to maintain the unit's temperature and thus provide the necessary functioning heat. The neem oil remains deposited in the depositary tank; the situation is approved to run from end to end of the oil tank inside the rear of the PV unit. The backside cooling neem oil tank

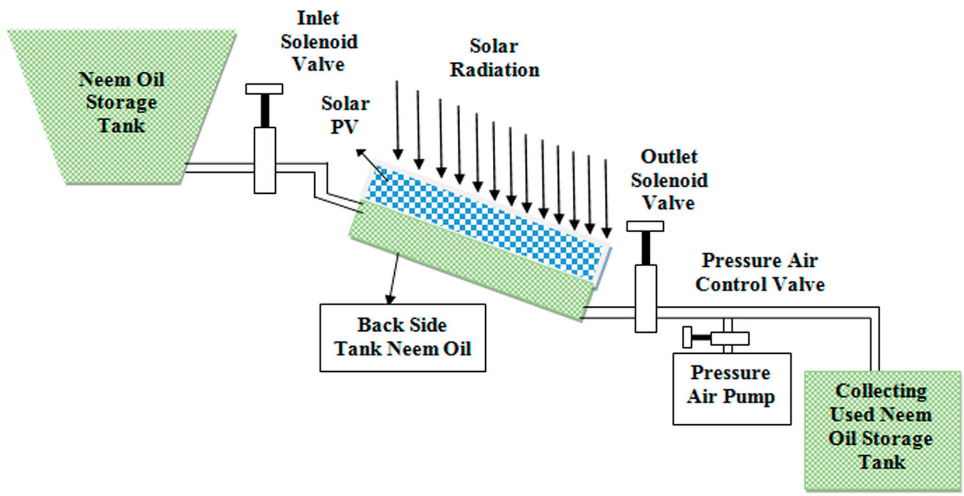

Fig. 1 Representation diagram of the proposed system

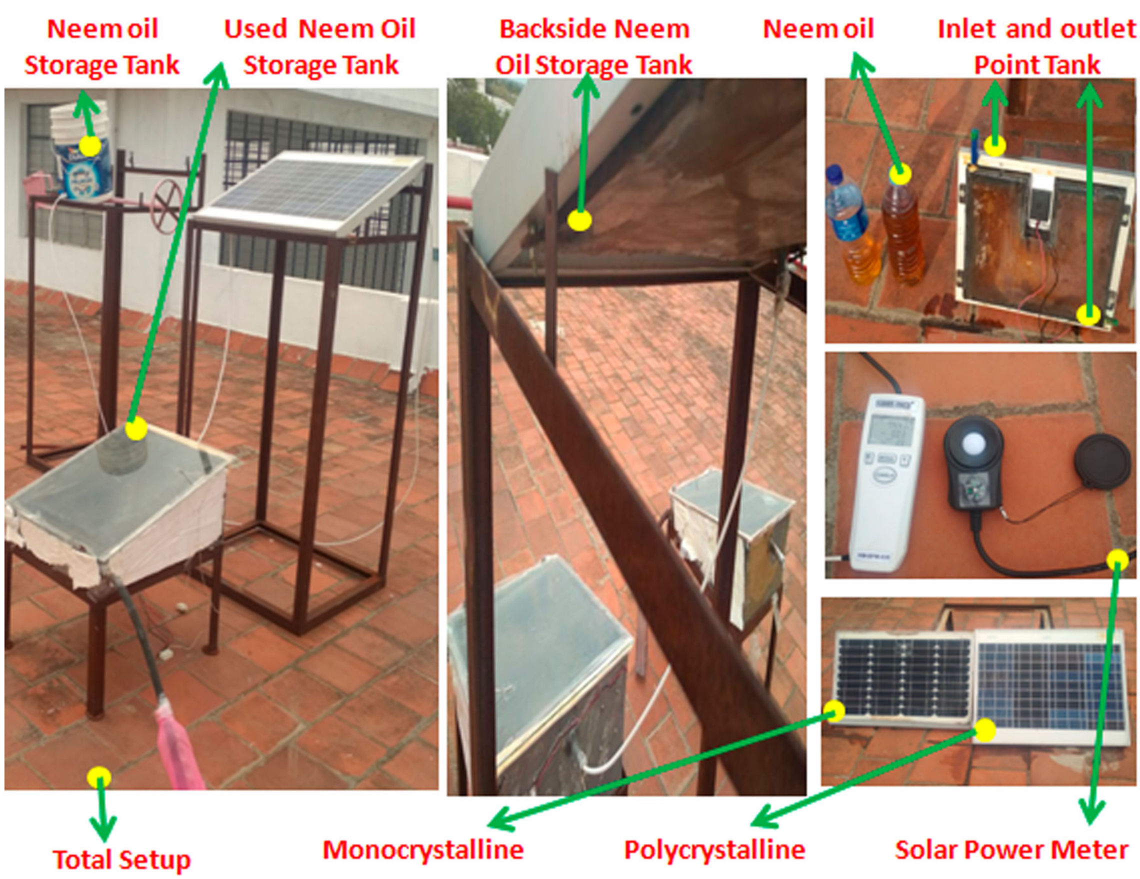

Fig. 2 Investigational setup

is not filled with all 1.6 inches but only with 10:2 because of the air circulation requirement. The method does not use any active oil circulation techniques. Here, the neem oil is active in the limitation of the absorption heat of solar PV and increases the operational efficiency of the solar PV. The oil runs keenly on the unit and away from the unit. Thus, excited oil is together in the depositary tank. The functioning investigation on monocrystalline and polycrystalline solar PV, both with neem oil and without backside cooling actions, was practically done on 05/04/2023—the neem oil acts as a coolant.

The experimental procedure of the proposed method involves taking two models of solar PV panels into analysis. One is monocrystalline, and the other is polycrystalline. Both models use dual analysis, including cooling with neem oil and another without neem oil. The monocrystalline and

Table 1 Requirement of solar PV unit

Requirement	Monocrystalline Unit	Polycrystalline Unit
Maximum Power (P_m)	50Watts (W)	50Watts (W)
Maximum Voltage (V_m)	18.50 Volt (V)	19.8 Volt (V)
Maximum Current (I_m)	2.75 Amps (A)	2.52 Amps (A)
Open-Circuit Voltage (V_{oc})	22.14 Volt (V)	24.0 Volt (V)
Short-Circuit Current (I_{sc})	2.89 Amps (A)	2.76 Amps (A)
Efficiency (η)	15–24%	

polycrystalline solar PV is analyzed for including a cooling tank with neem oil and a nonincluding cooling tank. The comparative analyses taken into account, including the backside cooling tank with neem oil panel performance, are better than without backside cooling tank panel—the comparison of including cooling neem oil monocrystalline and polycrystalline panels. The performance of polycrystalline panels is best compared to that of monocrystalline panels.

The process of the proposed method for monocrystalline and polycrystalline solar PV backside tanks involves collecting neem oil from storage tanks, and the neem oil needs to be filled in the backside tank completely because the oil requires some breathing space. The breathing space of PCM is to enhance the heat-withstand efficiency. The backside neem oil is replaced every 30 min. The neem oil acts as PCM; solar PV heat is transferred to the neem oil. Regulate and control the temperature of solar PV. The inlet, outlet solenoid valve, and pressure air control valve are used to regulate and control the flow of neem oil from the oil storage tank via the backside solar PV tank to the used oil storage tank. The performance of solar PV is enhanced. The used oil is collected in a used oil storage tank. The proposed method of collecting used neem oil tank oil is reused again, and the temperature is totally reduced. Generally, the conventional method does not have any cooling techniques. The proposed method is analyzed in two ways: one is monocrystalline and polycrystalline without a cooling system, and another is monocrystalline and polycrystalline with a cooling system. The specification of monocrystalline and polycrystalline is represented in Table 1.

2.1 Characteristics analysis of existing and proposed oil

Table 2 represents substantial portions of existing edible and proposed neem oils. The comparative analysis of existing and proposed oil is described as follows: The existing edible Cocos Nucifera and gingelly oil characteristics do not match the proposed neem oil. They consider characteristics such as thickness, kinematic viscosity, thickness index, saponification value, iodine value, pour factor, and flash factor. However, the mentioned characteristics of edible groundnut oil are similar to those of the proposed neem oil. In the existing analysis, solar PV is used in the above-mentioned edible oil as a coolant. For this, the analysis of the solar PV efficiency is increased with the help of groundnut oil. The groundnut oil functioning is superior to Cocos Nucifera and gingelly oil. The proposed method of neem oil characteristics is also the same in groundnut oil. Neem oil is suitable for acting as a coolant in solar PV. Neem oil acts as a PCM. So, the temperature of neem oil is limited, and solar PV Efficiency is enhanced. The nomenclature is added above the introduction.

The oil thickness represents mass per unit volume at the standard temperature and pressure. The thickness or density of the oil is denoted by Eq. (1) [48].

$$\rho = \frac{\mathrm{m}}{\mathrm{V}}\mathrm{kg/m^3} \tag{1}$$

The kinetic viscosity of the oil changes as temperature increases. The kinetic viscosity is displayed in Eq. (2) [48]

$$\text{Kinematic viscosity at t}^\circ = \frac{\text{absolute viscosity at t}^\circ}{Thicknessatt^\circ}\mathrm{mm^2/sec} \tag{2}$$

and the viscosity concerning the temperature in Eq. (3) [31],

$$\eta = ae^{-bT} \tag{3}$$

The viscosity and thickness of the oil are reduced by increasing the temperature, and the thickness of the oil is enhanced at the same viscosity. As per the standard of the American Society for Testing and Materials (ASTM), the velocity–temperature relationship equation is [13]:

$$\log_{10}\log_{10} Z = A - B\log_{10} T \tag{4}$$

As per the ASTM standard, the viscosity index is calculated by Eq. 5 [13].

$$\mathrm{VI} = \frac{a-b}{a-c} \times 100 \quad \mathrm{cSt} \tag{5}$$

All the equation parameters are described in Table 1. Nomenclature. The output power of solar PV is calculated using the equation below: [13]

$$P = V_{\mathrm{oc}} \times I_{\mathrm{sc}} \quad \mathrm{Watts} \tag{6}$$

Table 2 Substantial belongings of oil [48, 49]

Requirement	Thickness (g/ml)	Kinematic Viscosity @40 °C (mm^2/sec)	Viscosity Index (cSt)	Saponification Value	Iodine Value	Pour Factor °C	Flash Factor °C
Cocos Nucifera oil	0.913	28.1	152	250–263	4–12	18	238
Gingelly oil	0.917	32.02	212.9	185–197	102–118	- 13	313
Groundnut oil	0.912	37.80	142	184–195	82–95	5	334
Proposed System-oil							
Neem oil	0.912	48.5	165.4	175	65–80	9	343
Latent Heat Value				3.882×10^7 J/Kg			

Uncertainty of Equipment				
Equipment	Appropriateness	Boundaries	Uncertainty	%inexactness
Temperature Sensor	± 0.8ºC	0-100ºC	± 0.17 to 0.47ºC	0.48%
Solar Power Meter	± 1W/m^2	0–2400 W/m^2	± 1W/m^2	2.47%
Wattmeter	0.4W	0-100W	0.4W	0.99%

The efficiency of solar PV is calculated using the equation below [31]:

$$\eta_{pv} = \frac{P}{I(t) \times A_{pv}} \times 100 \tag{7}$$

2.2 Characteristics and advantage of neem oil

Generally, solar PV uses organic and inorganic materials for cooling techniques. Inorganic PCM faces problems like corrosiveness and instability, whereas organic PCM has no corrosives, low or no undercooling, and chemical and thermal stability. The neem oil is organic, and Table 5 describes the following thermal, physical, chemical, environmental, and economic characteristics: The neem oil has a good thermal range, is physically high in density, is chemically stable and noncorrosive, is environmentally pollution-free, reusable, and recyclable, and is economically low-cost and easy to dispose of.

Commonly, any PCM used for cooling purposes should have low thermal conductivity, stability, and cycling. The neem oil has fulfilled all the limitations, so it is suitable for PCM used in monocrystalline and polycrystalline solar PV systems.

3 Results analysis

3.1 Neem oil

The highest amount of sunlight of 940 W/m^2 is inward at 1.00 pm, the lowest amount of sunlight of 80 W/m^2 is inward at 6.00 pm, and standard sunlight inward through the daylight (05.04.2023) is 633 W/m^2. The highest ambient heat is 41.4 °C, as evidenced at 1.00 pm. The least ambient heat is 26.4 °C, established at 09.00 am, and the standard heat throughout the daylight is 32.83 °C (Table 3).

Figure 3 shows a graphical view of ambient temperature with respect to time. The highest, smallest amount, and standard unit heat for the monocrystalline unit, not including cooling, are 68.5 °C, 30.3 °C, and 51.3 °C, and including cooling, 66.3 °C, 28 °C, and 49.19 °C, respectively. The neem oil, since the coolant has an outcome within a standard, decreased the monocrystalline unit and polycrystalline unit heat by 2.29% and 4.34%, respectively.

Figure 4 indicates the difference in sunlight concerning time. The most significant and smallest amount of sunlight occurs at 1:00 pm and 6:00 pm. The unit heat amplifies with exposure to sunlight. Figure 5 indicates ambient temperature and solar irradiation with respect to time.

From Table 3, the monocrystalline and polycrystalline highest values of output power without cooling systems are 37.3 W and 39.4 W, respectively, at 1.00 pm. However, monocrystalline and polycrystalline have the highest values of output power, with cooling systems of 39.9 W and 41.6 W,

Table 3 Neem oil as a coolant

Time of Days (Hours) (T)	Solar irradiation (W/m^2) (G)	Ambient temperature ((ºC) -T_a)	Monocrystalline unit, not including cooling arrangement		Polycrystalline unit, not including cooling arrangement		Monocrystalline unit, including the cooling arrangement				Polycrystalline unit, including cooling arrangement			
			Module temperature ((ºC) M_{MT})	Output power-Watts (P)	Module temperature ((ºC) P_{MT})	Output power-Watts (P)	Module temperature ((ºC) M_{MT})	Voltage-Volt (V_{oc})	Current-Amp (I_{sc})	Output power-Watts (P)	Module temperature ((ºC) P_{MT})	Voltage-Volt (V_{oc})	Current-Amp (I_{sc})	Output power-Watts (P)
9	400	26.4	30.3	19.1	29.9	22.1	28	18.7	1.13	21.1	27	20.9	1.2	25
10	710	30.3	50.2	29.2	49.1	31.2	48.3	19.6	1.6	31.3	47.2	21.2	1.62	34.3
11	890	33.7	57.2	37.1	56.9	38.9	55.1	20.6	1.91	39.3	54.9	21.4	1.91	40.9
12	910	38.4	64.2	36.2	63.1	38.6	62.8	20.4	1.88	38.4	61.2	21.3	1.9	40.4
13	940	41.4	68.5	37.3	67.1	39.4	66.3	20.7	1.93	39.9	65.2	21.6	1.93	41.6
14	860	35.6	56.7	34.2	55.1	37	54.7	19.1	1.9	36.2	53	20.1	1.98	39.8
15	700	34.2	56.3	26.6	55.2	28.9	54.2	18.9	1.52	28.7	53.1	19.8	1.56	30.9
16	520	32	51.1	19.6	50.3	22	49	18.1	1.2	21.7	48.2	19.6	1.26	24.6
17	320	29.6	42.7	11.4	41.2	14	40.2	13.6	1	13.6	39.1	14.5	1.13	16.3
18	80	26.7	35.8	1	34.1	4	33.3	4	0.55	2.2	32	4.7	1.1	5.1

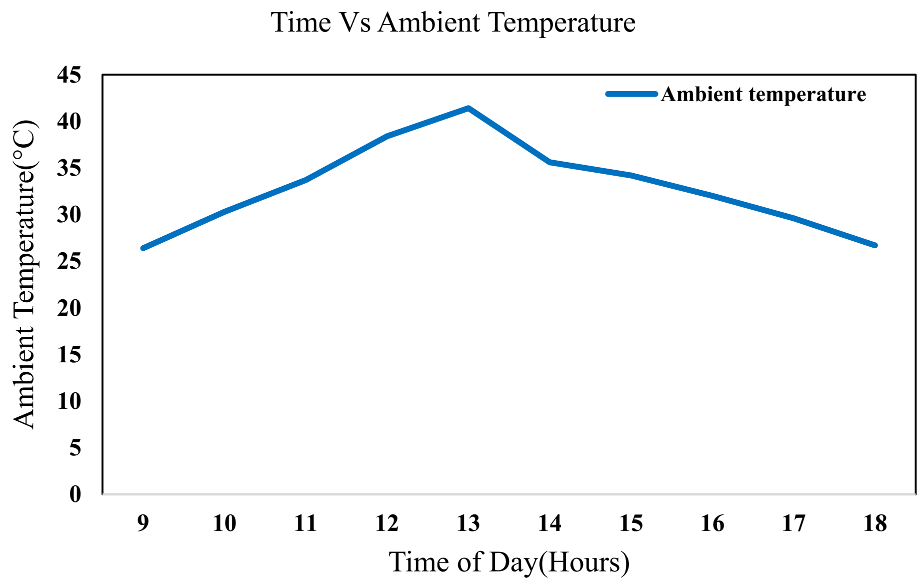

Fig. 3 Ambient temperature versus time

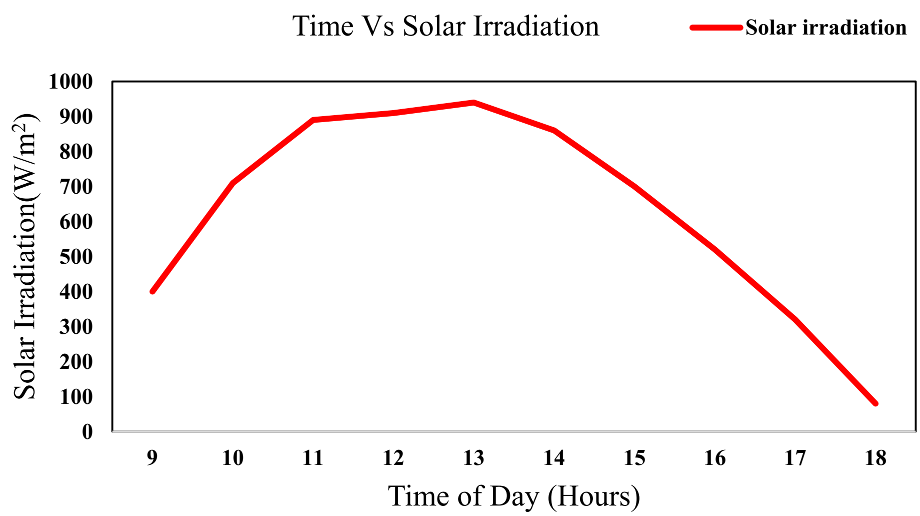

Fig. 4 Solar irradiation versus time

respectively. The monocrystalline and polycrystalline units contain improved standard efficiency of 15.0% and 17.8% through the cooling unit. Table 4 summarizes neem oil as a coolant.

From 3 to 4, the ambient temperature and solar irradiation have the highest impact on output power. Figure 5 is to describe the ambient temperature, which is to increase gradually from morning to afternoon and decrease gradually from afternoon to evening depending on solar irradiation. The ambient temperature is increased by increasing the panel temperature; the performance of the PV panel is reduced. The solar irradiation, ambient temperature, and output power of monocrystalline and polycrystalline neem oil cooling systems at 10 am are 710 W/m^2, 30.3℃, 31.3 W, and 34.3 W, respectively. At 1 pm, it is 940 W/m^2, 41.4 °C, 39.9 W, and 41.6 W.

3.2 Output power with respect to time

Figure 6 shows the defined output power without a cooling system with respect to time. Without a cooling system, both monocrystalline and polycrystalline absorption temperatures are not controlled, so the efficiency of solar PV is reduced. Generally, the temperature of solar PV is increased gradually from morning to afternoon (reaching the highest value), and after that, the temperature gradually decreases (evening). From the figure, the morning monocrystalline and polycrystalline temperatures are 30.3 °C and 29.9 °C, respectively. Then, the afternoon 1.00 pm temperature is 68.5 °C and 67.1 °C, respectively.

Figure 7 describes the output power of the cooling system with respect to time. The cooling system (neem oil), both monocrystalline and polycrystalline, regulates the temperature, and the efficiency of solar PV is enhanced. From

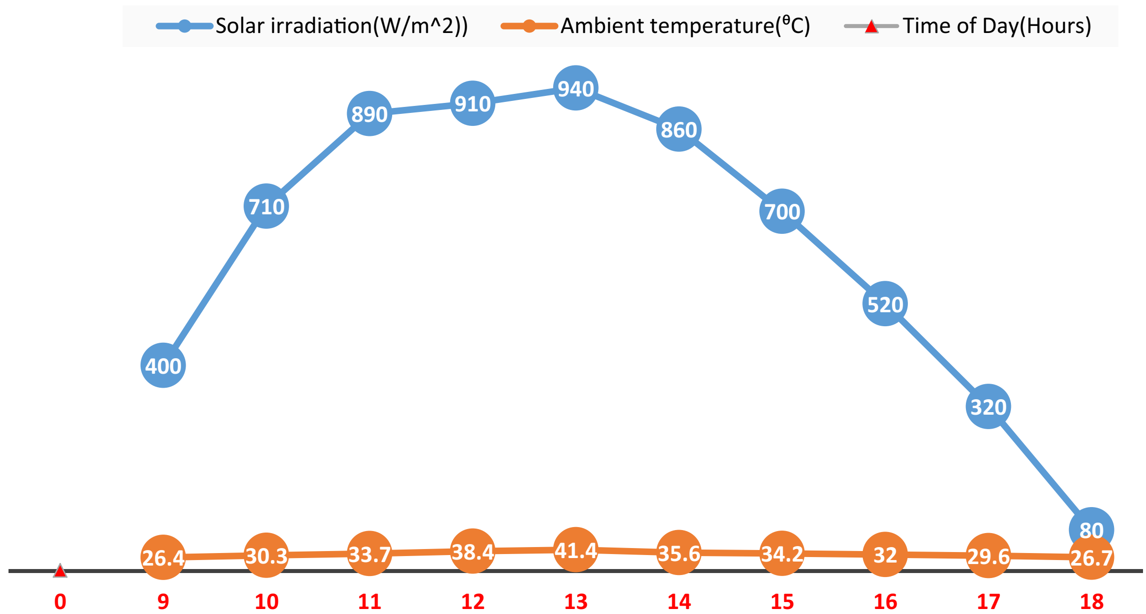

Fig. 5 Ambient temperature and solar irradiation with respect to time

Table 4 Evaluation of PV unit through cooling construction

Edible oil	Decrease in unit temperature for the monocrystalline unit, including cooling (%)	Decrease in unit temperature for the polycrystalline unit, including cooling (%)	Enhancement in efficiency for the monocrystalline unit, including cooling (%)	Enhancement in efficiency for the polycrystalline unit, including cooling (%)
Neem oil	2.29	4.34	15.0	17.80

the figure, the monocrystalline and polycrystalline temperatures are 28 °C and 27 °C, respectively. Then, the afternoon 1.00 pm temperature is 66.3 °C and 65.2 °C, respectively.

From the comparative analysis of with and without cooling systems, the performance of monocrystalline and polycrystalline cooling systems using neem oil is superior as compared to without cooling systems.

In Table 3 output power is calculated by using Eq. (6).

$$P = V_{oc} \times I_{sc} \text{Watts}$$

Time (T)—1 pm, solar irradiation (G)- 940 W/m^2, ambient temperature (T_a)-41.4 °C.

Monocrystalline panel,

V_{oc}-20.7 V; I_{sc}-1.93A.

From Eq. (6),

$P = 20.7 \times 1.93$.

$P = 39.9$ W.

Polycrystalline panel,

V_{oc}-21.6 V; I_{sc}-1.93A.

From Eq. (6),

$P = 21.6 \times 1.93$.

$P = 41.6$ W.

4 Summarization of functioning of neem oil as a coolant

Table 4 signifies the evaluation of the decreased unit heat and enhancement in efficiency for not including and including cooling intended in favor of the monocrystalline and polycrystalline units. It is concluded that the polycrystalline unit has enhanced the functioning of the unit beneath the complete cooling intermediate. In the proposed design process, the polycrystalline unit function improved more than the monocrystalline unit—the monocrystalline and polycrystalline unit function cooling intermediate has created better functioning.

5 Comparative analysis and benefit

5.1 Efficiency and reduced temperature of neem oil

The section discusses the efficiency and economic benefits of neem oil as compared with edible oil and the characteristics, advantages, and limitations of neem oil. Table 3 represents monocrystalline and polycrystalline efficiency with cooling

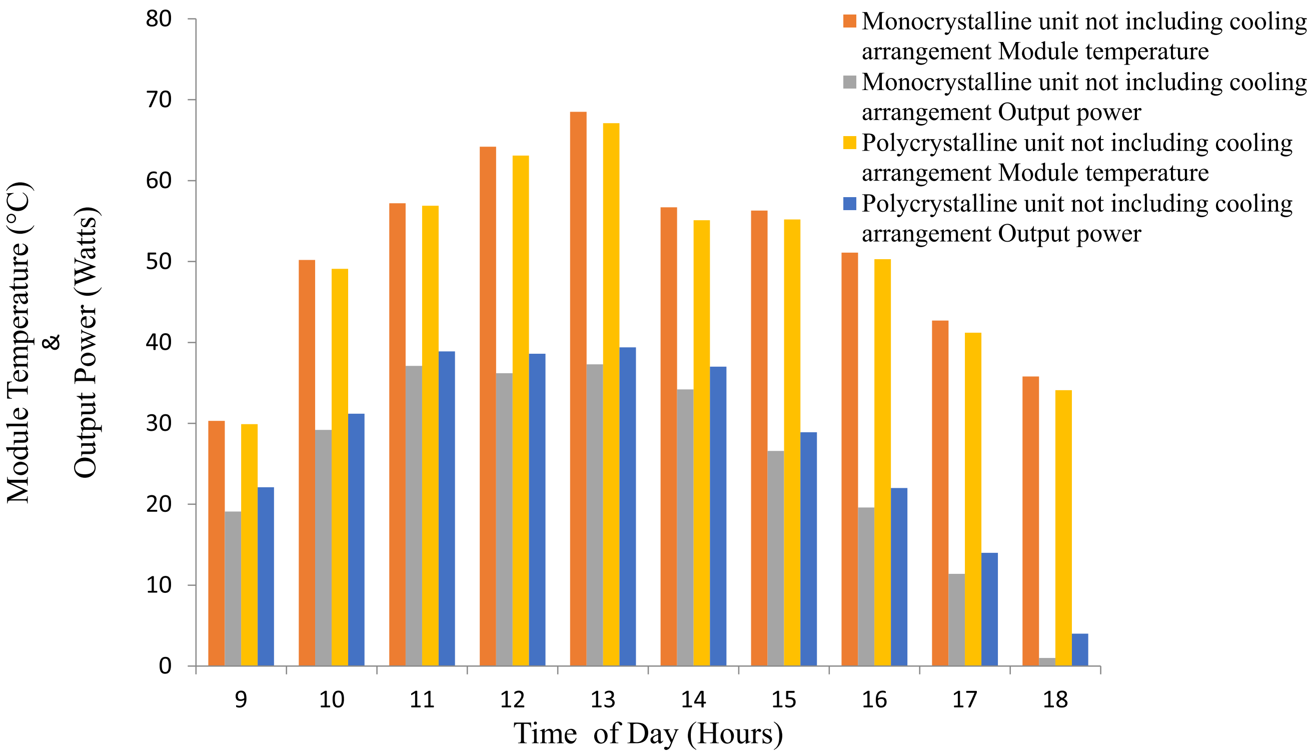

Fig. 6 Output power for not including cooling unit through time

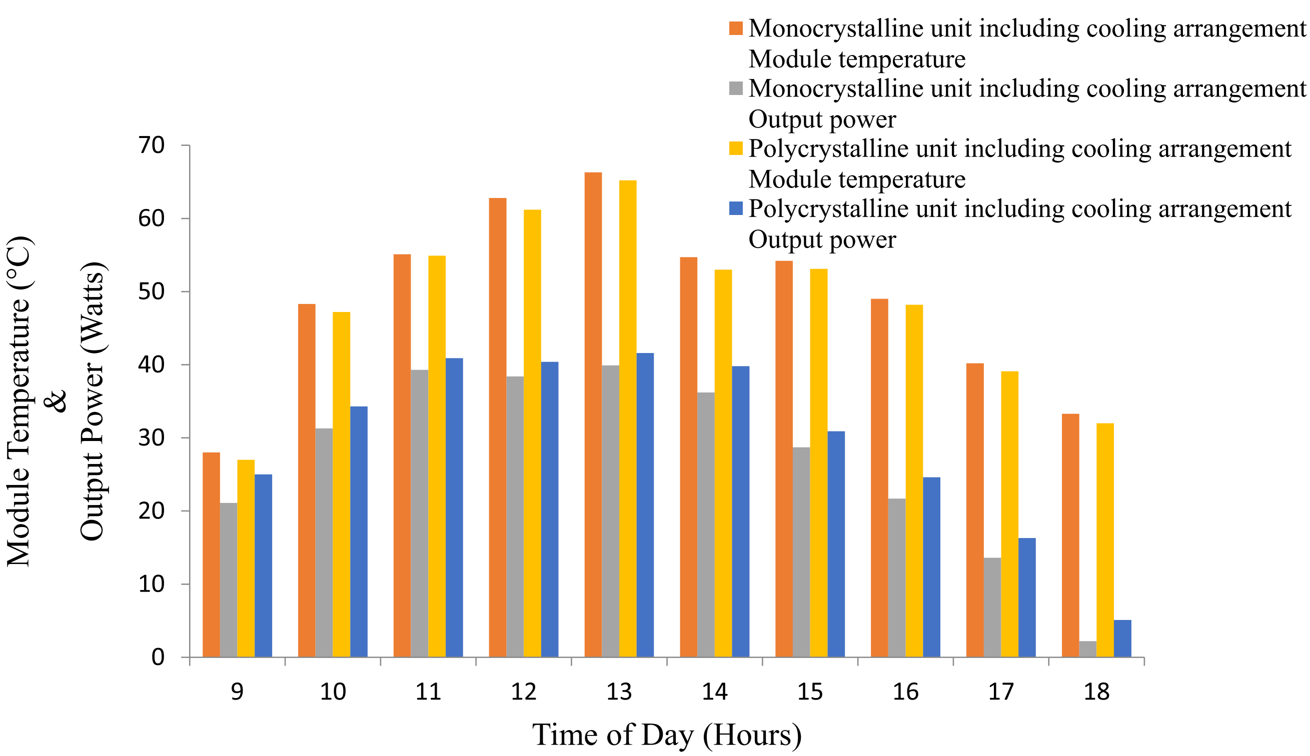

Fig. 7 Output power for including (neem oil as a coolant) cooling unit through time

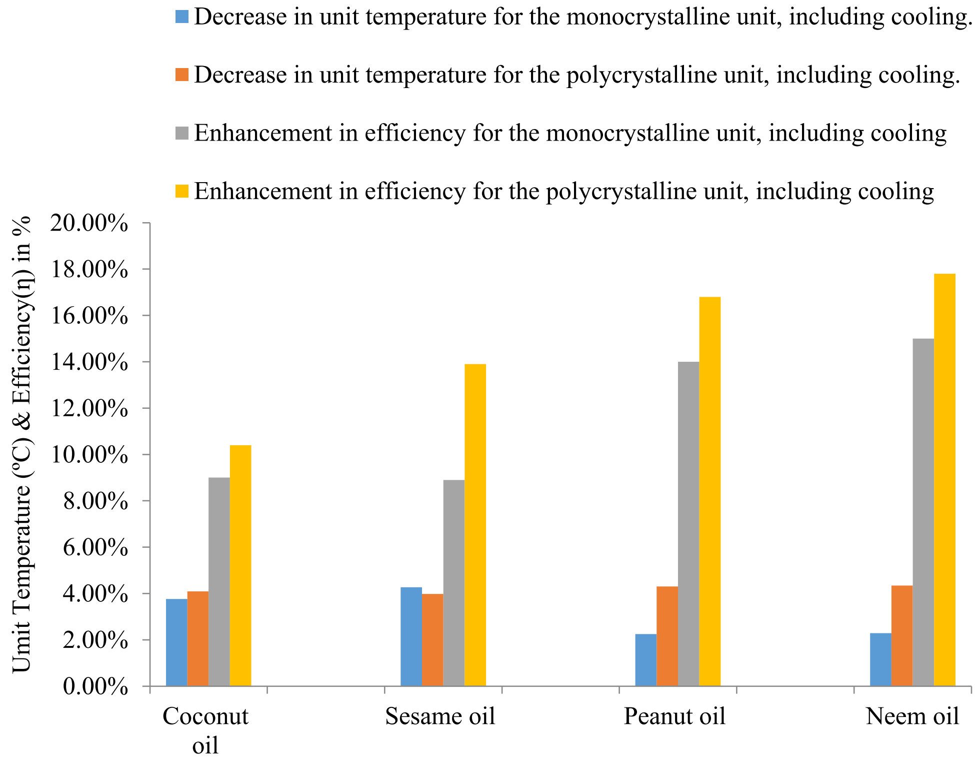

Fig. 8 Comparative analysis of solar PV different edible oils with proposed neem oil

systems and a decrease in solar PV temperature with cooling systems. Figure 8 describes the monocrystalline and polycrystalline efficiency and decrease in solar PV temperature with a cooling system by using different edible oils (coconut oil, sesame oil, peanut oil) and the proposed neem oil. The monocrystalline and polycrystalline with neem oil cooling system temperatures are reduced to 2.29% and 4.34%, respectively, as compared with edible oil monocrystalline and polycrystalline temperatures: coconut oil is 3.76% and 4.09%, sesame oil is 4.27% and 3.98%, and peanut oil is 2.25% and 4.30%, respectively. The monocrystalline and polycrystalline cooling system with neem oil efficiency is improved by 15.0% and 17.80% as compared with edible oil monocrystalline and polycrystalline efficiency: coconut oil is 9.0% and 10.40%, sesame oil is 8.90% and 13.90%, and peanut oil is 14.0% and 16.80%, respectively. The comparative analysis of monocrystalline and polycrystalline cooling systems uses the proposed neem oil as the superior one because a high percentage reduces the temperature of solar PV as compared with all three different edible oils. At the same time, the competence of solar PV is improved by a high percentage as compared with all three different edible oils. The comparative analysis of neem oil performance, characteristics, advantages, and PCM limitations is shown in Table 5.

5.2 Cost analysis

The monocrystalline and polycrystalline methodologies have backside cooling tank arrangements. The setup was constructed with the help of the following equipment: solar PV (monocrystalline and polycrystalline), neem oil storage tank, solar PV backside cooling tank, collecting used neem oil storage tank, inlet and outlet solenoid valve, pressure air pump, and flexible hose. The cost of monocrystalline and polycrystalline panels is Rs. 2300 and Rs. 2500, respectively. All other equipment and setup cost is Rs. 1500. In the efficiency point, the neem oil cooling system is cost-effective because it uses waste and rehashed neem oil. After usage, the disposal of neem oil is very easy and cost-effective as compared with inorganic cooling systems. The cost analysis of the proposed solar PV system is shown in Table 6.

6 Conclusion

The work evaluated the possibility of rear-exterior cooling of the monocrystalline and polycrystalline units with the use of neem oil as a coolant. Currently, the ecologically gracious edible is used as an exchange for mineral oil. The unit's function, including and not including coolant, is expe-

Table 5 Comparative analysis of solar PV with different edible oils [50]

Edible oil	Decrease in unit temperature for the monocrystalline unit, including cooling (%)	Decrease in unit temperature for the polycrystalline unit, including cooling (%)	Enhancement in efficiency for the monocrystalline unit, including cooling (%)	Enhancement in efficiency for the polycrystalline unit, including cooling (%)
Coconut oil	3.76	4.09	9.0	10.40
Sesame oil	4.27	3.98	8.90	13.90
Peanut oil	2.25	4.30	14.0	16.80

Characterictics and advantages of neem oil (Organic PCM)

Thermal	Large temperature range	High blending heat	There is no cooling
Physical	High Density	Low volume	Extension
Chemical	Stable	Noncorrosive	Nonexplosive, Noninflammable and Nontoxic
Environmental	Recyclable	Reusable	Pollution-free
Economic	Cheap and cost-effective	Odor-free	Easy Dispose Of

PCM limitation

Limitation	Low thermal conductivity	Low thermal Stability	Low thermal Cycling

Table 6 Cost analysis of proposed solar PV system

Manufacturing and procedure factor	Monocrystalline solar PV (Cost in Rs.)	Polycrystalline solar PV (Cost in Rs.)
Solar PV	2300	2500
Making Cost	1500	1500
Protection Cost	4 Rs/day	4 Rs/day
Execution cost	6 Rs/day	6 Rs/day
Neem oil Cost	15Rs/day	15 Rs/day

riential for neem oil. In the neem oils, the competence of the monocrystalline and polycrystalline units simplifies to 15.0% and 17.80%, respectively. The experimental outcome the work proposes is that neem oil can be used as a coolant and exchanged for the toxic mineral oil or water in a container of shortage. Using neem oil as a coolant is a cost-reduction atmosphere that can be incorporated keenly into the unit to uphold the necessary functioning heat. The oil's buildup temperature can be used for the temperature submission.

In future, superior cooling materials, such as nano-based materials or mixed combinations of organic and inorganic materials, will be used in solar PV cooling techniques. To reduce the PV panel temperature and enhance the output power and efficiency, the proposed method concludes the following:

i. Depending on its characteristics, neem oil is suitable for phase-changing materials (PCM) in solar PV.
ii. The monocrystalline and polycrystalline cooling systems with neem oil temperatures are reduced to 2.29% and 4.34%, respectively.
iii. The monocrystalline and polycrystalline cooling systems with neem oil efficiency are improved by 15.0% and 17.80%, respectively.
iv. The monocrystalline and polycrystalline neem oil cooling systems' maximum output power at 1.00 PM is 39.9 and 41.6 W, respectively.
v. Compared with edible oil, neem oil is superior, and compared with inorganic materials, organic neem oil is easily disposed of.

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Data availability The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest The authors declare no potential conflicts of interest concerning this article's research, authorship, and publication.

Competing interests To the best of my knowledge and belief, any actual, perceived or potential conflicts between my duties as an employee and my private and business interests have been fully disclosed in this form following the journal's requirements.

Ethical approval This material is the author's original work, which has not been previously published elsewhere. The paper is not currently being considered for publication elsewhere. The paper reflects the author's research and analysis truthfully and completely.

Consent to participate I have been informed of the risks and benefits involved, and all my questions have been answered satisfactorily. Furthermore, I have been assured that a research team member will also answer any future questions. I voluntarily agree to take part in this study.

Consent to publish Individuals may consent to participate in a study but object to publishing their data in a journal article.

Research involving human participants and animals The authors at this moment assure that this research does not involve any human participants or animals.

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