JTERA (Jurnal Teknologi Rekayasa), Vol. 8, No. 2, Desember 2023, Hal. 271-278
Terakreditasi “**Peringkat 3**” oleh Kemenristek/BRIN, Nomor SK: 85/M/KPT/2020
DOI: 10.31544/jtera.v8.i2.2023.271-278

p-ISSN 2548-737X
e-ISSN 2548-8678

The Effect of Light Type and Distance on Indoor Photovoltaic System

Dessy Ade Pratiwi[#], Andi Ibrahim Soumi, Wafiq Kurniawan
Universitas Muhammadiyah Surakarta
Jl. A. Yani, Mendungan, Pabelan, Kec. Kartasura, Kabupaten Sukoharjo, Jawa Tengah 57162, Indonesia
#dap815@ums.ac.id

Abstrak

Sumber energi alternatif dan penyimpanan energi memainkan peran penting dalam menjaga dan menyediakan energi. Penerapan *indoor photovoltaic* menjadi salah satu alternatif dalam pengelolaan energi menggunakan sumber cahaya buatan. Namun, salah satu kendala utama yang dihadapi dalam pengoperasian panel *photovoltaic* adalah masalah signifikan dari efisiensi listrik yang rendah pada sel *photovoltaic*. Tujuan dari penelitian ini adalah untuk mengetahui kinerja *indoor photovoltaic* dengan variasi lampu LED dan CFL dengan kapasitas 5W dan 10W, serta variasi jarak yang diberikan yaitu 25 cm dan 30 cm. Metode penelitian yang dilakukan adalah melakukan pengujian sensor temperatur menggunakan sensor MAX 6675 dan sensor tegangan dan arus listrik menggunakan sensor MAX471. Intensitas cahaya yang dihasilkan lampu dibaca sensor. Daya listrik yang dihasilkan oleh *photovoltaic* disimpan pada baterai. Hasil yang dibaca oleh sensor-sensor ditampilkan pada serial monitor. Hasil penelitian menunjukkan bahwa peningkatan jarak antara lampu dan bidang cahaya mengakibatkan penurunan intensitas cahaya. Hal ini dapat dilihat pada lampu CFL jarak lebih jauh antara sumber cahaya dan modul *solar cell* yang mengakibatkan intensitas cahaya pada lampu CFL 5W 30 cm rendah. Penurunan efisiensi pada sistem *photovoltaic* dalam ruangan berpengaruh pada temperatur bahwa peningkatan temperatur *photovoltaic* menyebabkan penurunan efisiensi arus dan tegangan keluaran listrik.

Kata kunci: energi terbarukan, *photovoltaic*, LED, CFL, jarak

Abstract

Alternative energy sources and energy storage play an important role in maintaining and providing energy. The application of indoor photovoltaics is one alternative in energy management using artificial light sources. However, one of the main obstacles faced in the operation of photovoltaic panels is the significant problem of low electrical efficiency in photovoltaic cells. The purpose of this research is to find out the performance of indoor photovoltaic with variations of LED and CFL lamps with a capacity of 5W and 10W, as well as the variation of the given distance which is 25 cm and 30 cm. The research method used is to test the temperature sensor using the MAX 6675 sensor and the voltage and current sensor using the MAX471 sensor. The light intensity produced by the lamp is read by the sensor. The electricity produced by photovoltaics is stored in the battery. The results read by the sensors are displayed on the serial monitor. The results of the research show that increasing the distance between the lamp and the light field results in a decrease in light intensity. This can be seen in the CFL lamp with a longer distance between the light source and the solar cell module which results in the light intensity of the 5W 30 cm CFL lamp being low. The decrease in the efficiency of photovoltaic systems in the room has an effect on the temperature that the increase in photovoltaic temperature causes a decrease in the efficiency of the current and voltage of the electricity output.

Keywords: *renewable energy, photovoltaic, LED, CFL, distance*

I. INTRODUCTION

Nowadays, alternative energy sources such as water energy, wind energy, and solar energy have become very popular [1]-[3]. Alternative energy sources and energy storage play an important role and providing high-quality energy to about 20% of global energy needs [4], [5]. Renewable and environmentally friendly energy sources, such as solar-based photovoltaics are one of the most promising options due to their lower cost, ease of installation, and economy[6]-[8].

Many researchers are studying the efficiency of thermal devices associated with solar energy by

Diterima: 22 Oktober 2023; Direvisi: 11 Desember 2023; Disetujui: 16 Januari 2024

conducting laboratory tests using artificial light sources as heat sources commonly called Indoor Photovoltaic (IPV). The application of IPV can significantly reduce the maintenance costs of indoor electrical devices [9]. In a building or office environment, reliable surrounding lighting usually comes from power sources such as light bulbs, neon lamps, compact neon (CFL) lights, halogen lamps, and LED lamps [10].

However, one of the main obstacles faced in the operation of the photovoltaic panel is the significant problem of the low electrical efficiency of the photo-voltaic cell [11]-[13]. It is important to note that the efficiency of Photovoltaic plants is also affected by the operating temperature of Photovoltaic panels. Overheating caused by excessive light sources and high operating temperatures are the main reasons for the low electrical efficiency of photovoltaic cells [14].

In addition, to increase the intensity of light produced from artificial light sources, it is necessary to apply variations in distance to determine how much light intensity is produced [15]. Bayu et al conducted previous research on Indoor Photovoltaic experiments with 20º and 90º inclination variations and distances between 0.3 m – 1.5 m [15]. The type of module used is monocrystalline silicone with 50 Wp dimensional Pmas (530 x 670 x 30) mm. The source of fluid comes from tungsten halogen. The result of the study was that the light of the lamp from the halogen is stable after reaching 10 minutes with the wavelength range (380-780) nm, does not meet the BS EN 60904-9 standard radiation distribution calcification, the angle of inclination 20º and 90º has a degree of consistency with the test distance of 0.3 m and more than 0,3 m.

In addition, other research was conducted by Rapeepong Peamsuwan et al [14] on the application of heat sources from halogen lamps and sunlight. This study used 25 300 W 220 V tungsten halogen lamps. Halogen heights of 0.37, 0.67, 0.97, 1.27, and 1.57 m. resulted in increased distance between light and light field (Hd) resulting in a decrease in average light intensity. A comparison of the thermal efficiency of a solar collector under natural sunlight and artificial sunlight for a light field of 0.9 m x 0.6 m (absorbent plate) shows a percentage difference in thermal effectiveness of 3.98%

Another research conducted by Mengata et al [16] Characterized solar photovoltaic modules powered by artificial light for use as smart sensor sources. The types of modules used are monocrystalline silicon and polycrystalline modules. Meanwhile, the types of lamps used CFL, Halogen, LEDs, and light bulbs with values of 100-2000lx were evaluated with an uncertainty of ± (3% + 8) lx. The best performance results were recorded for the PV4 m-Si module that reached a power of up to 555.83 $\mu W/cm^2$ at 2000 lux under a light bulb. The lowest performance was achieved on the p-Si PV3 module of LED and CFL lamps with a power density range of only 0.16 $\mu W / cm^2$ at 100 lux.

The purpose of this study is to investigate indoor photovoltaic performance with the limitation of the problem regarding the given variation of LED and CFL lamps with capacities of 5W and 10W. As well as the given distance variation is 25 cm and 30 cm. The outer range of this research will produce parameters such as temperature, voltage, current, power, light intensity, and efficiency of indoor photo-voltaic systems.

II. Research Method

A. *Experiment Setup*

This photovoltaic experimental study was done in indoor conditions. Photovoltaic cells are placed on indoor photovoltaic test devices. The light source for photovoltaic testing is obtained from CFL and LED lamps. The CFL lamps used use capacities of 5W and 10W.

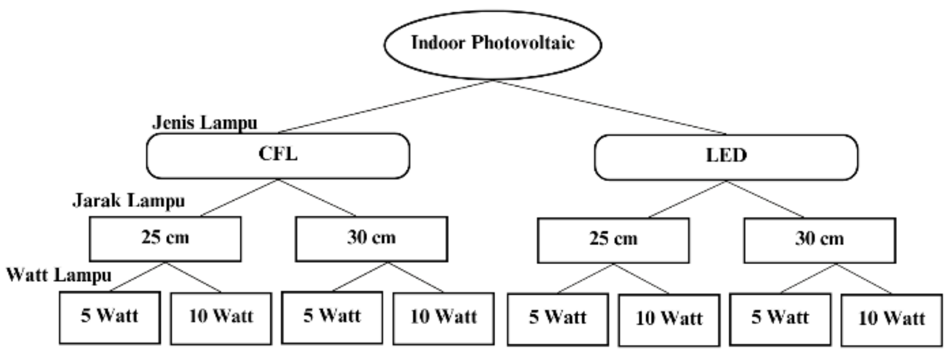
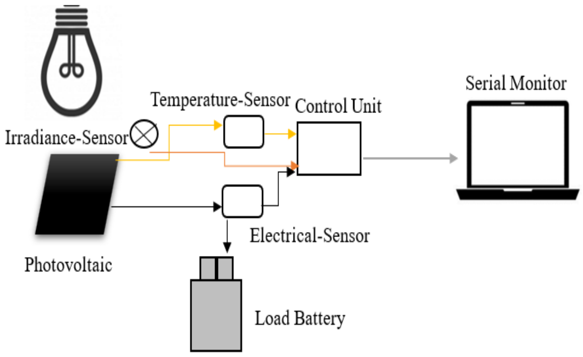


Figure 1. Scheme of the research



(a)

(b)

Figure 2. Scheme of the indoor photovoltaic system: (a) design, (b) implementation

Similar to the CFL light, the LED light used in this study uses a capacity of 5w and 10w. In this study, the distance between photovoltaic and light was set at 25 and 30 cm. Figure 1 is a test scheme of this photovoltaic research. The temperature sensor uses the MAX 6675 sensor and the voltage sensor and electrical circuit use the MAX471 sensor. The power generated by the photovoltaic is stored in the battery. The results read by the sensors are displayed on a serial monitor.

Photovoltaic can generate electric energy from the conversion of light intensity to photovoltaic [16]. To find out the power generated by the PV can use the formula [17]:

$$P = V.I \qquad (1)$$

where P is the power generated by photovoltaics, V is the voltage of photovoltaics, and I is the current. Photovoltaic efficiency is the ratio of the power produced by the energy of the intensity of light [18].

$$\eta = \frac{P}{I_r.A} \text{ x } 100\% \qquad (2)$$

where η is the photovoltaic efficiency, Ir is the intensity of light and A is the perimeter.

Figure 3. LED and CFL lamp

Figure 4. Photovoltaic module

Table 1. Photovoltaic specification

Specification	Value
Length (mm)	142
Width (mm)	88
Capacity (Wp)	5

B. Procedure Test

The test process is carried out in the following stages:

1. The test is performed by installing a lamp on the fitting of the test device.
2. The light is lit at the same time as the start of the data recording. The resulting data are module temperature data, voltage, and current as well as light intensity. The test scheme can be seen in Figure 2. Part a.
3. The type of light used is LED and CFL as shown in Figure 3.
4. The light distances are also varied in this study in each type of lamp. The distances given are 25 cm and 30 cm.
5. The capacity of the lamps attached to each distance is 5W and 10W. The illustration of the study can be seen in Figure 1.
6. The test was carried out for 60 minutes for each type and distance of the light.

Figure 4 is a photovoltaic module used in this research. The Photovoltaic has a capacity of 5 Wp. The photovoltaic specifications used in this study are shown in Table 1.

Table 2. Uncertainty value

Parameter	Uncertainty
Temperature (°C)	± 0.36
Voltage (V)	± 0.03
Current (A)	± 0.004
Power (W)	± 0.013
Light Intensity	± 0.63

C. Uncertainty Analysis

Measurement error is defined as the difference between the true value and the measured value. Uncertainty refers to the value that an error may occur. Uncertainty analysis provides a rational means of evaluating repeated data [15].

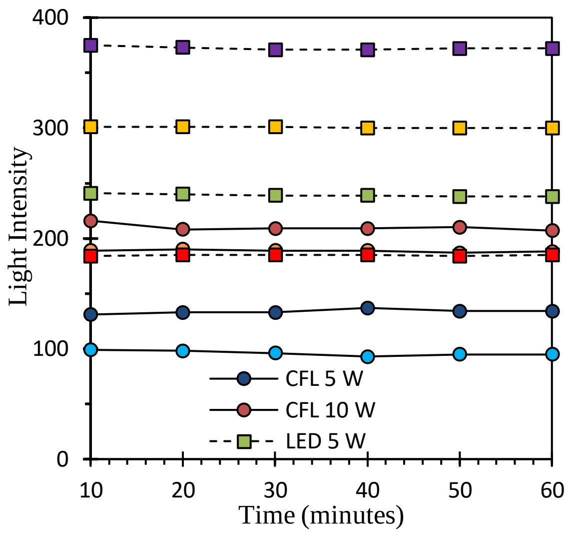
$$\frac{X_1 + X_2 + X_3 \ldots + X_n}{N} = \frac{1}{N}\sum_{i=1}^{N} X_i \quad (3)$$

$$SD = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \overline{X})^2}{N-1}} \quad (4)$$

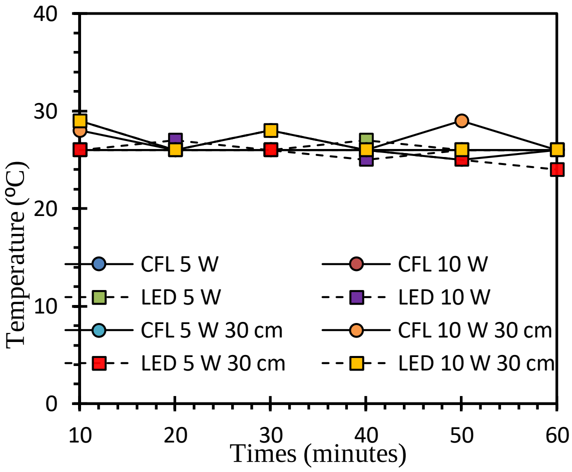
$$\sigma_m = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \overline{X})^2}{N(N-1)}} = \frac{SD}{\sqrt{N}} \quad (5)$$

III. Result and Discussion

From the results of the tests that have been carried out, the first graph results regarding light intensity and temperature are obtained. In Figure 5(a) shows the results of measuring the intensity of indoor photovoltaic light for 60 minutes with 2 types of lamps, namely CFL and LED, and variations in distance of 25 cm and 30 cm. From the graph, it can be seen that the light intensity for the 5W CFL lamp 30 cm has the lowest value of 93 lux, while the 10W LED lamp 25 cm has the highest light intensity value of 375 lux. This happens because the CFL has a longer distance between the light source and the solar cell module which results in a lower light intensity for the 5W 30 cm CFL lamp. Research on the effect of this distance was also conducted by Bayu et al [19], where an increase in the distance between the lamp and the light field resulted in a decrease in light intensity.



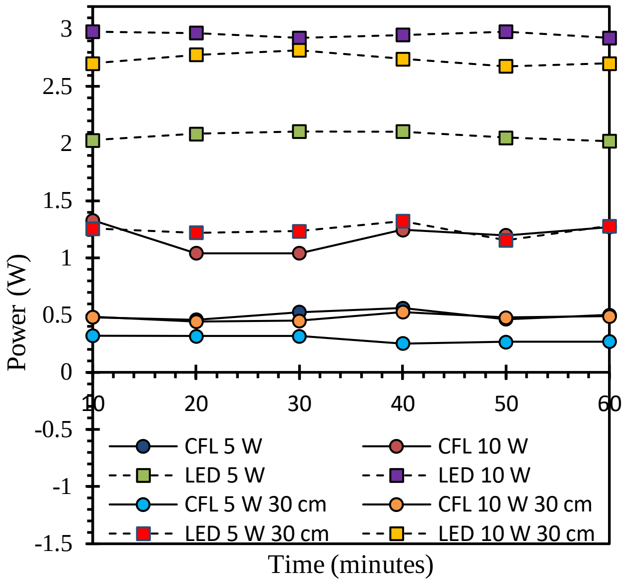
(a)



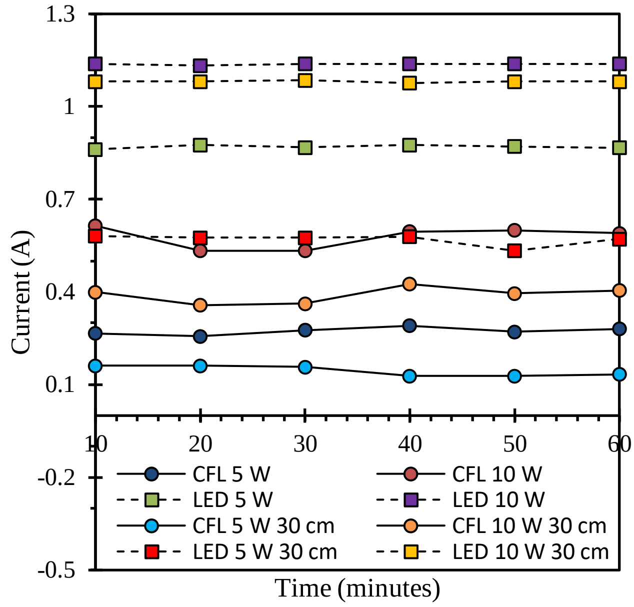
(b)

Figure 5. (a) Light intensity against time, (b) temperature against time

The temperature Figure 5(b) shows the temperature measurement results of the photovoltaic module. The temperature graph shows that the 5W 30 cm LED lamp has the lowest temperature value of 25ºC. In contrast, the highest temperature was recorded for the 10W 30 cm LED lamp at 29ºC. This occurs because the value of light intensity in the 10W 30 cm LED lamp is higher, resulting in a higher photovoltaic module temperature.

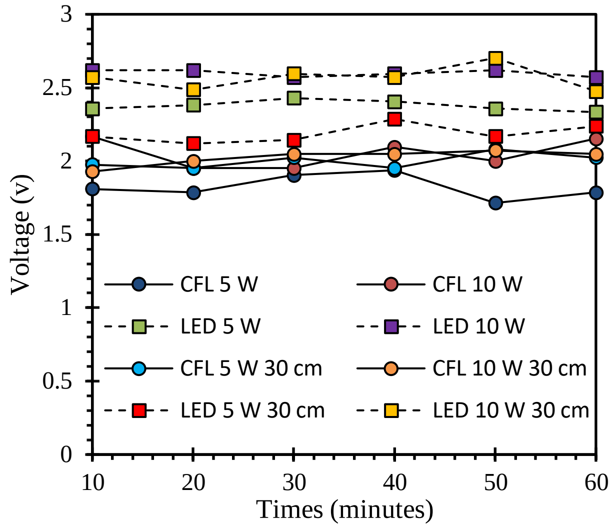


(a)

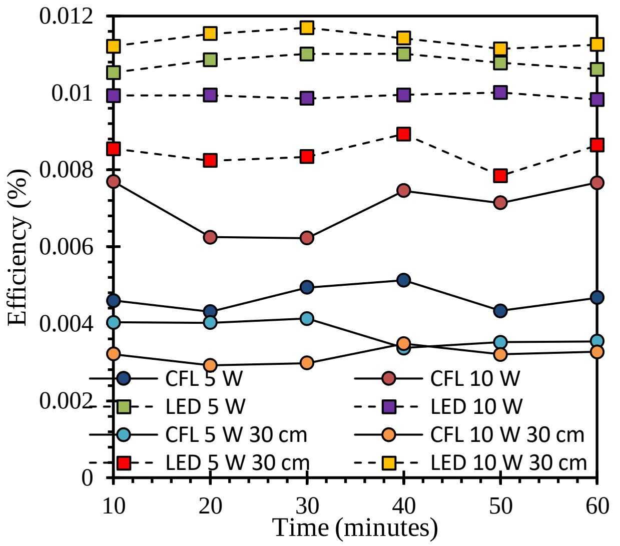


(b)

Figure 6. (a) Power against time, (b) current against time



(a)



(b)

Figure 7. (a) Voltage against time, (b) efficiency against time

In Figure 6(a), we can observe the graph of the power measurement results generated by different lamp types and distances. The power graph shows that the 5 W CFL lamp 30 cm has the lowest power value of 0.251 watts. While the 10W 25 cm LED lamp has the highest power value of 2.98 watts. This happens because the CFL has a longer distance between the light source and the solar cell module which results in low power on the 5W 30 cm CFL lamp. Figure 6(b), shows the current measurement results of the indoor photovoltaic system. The graph shows that the current for the 5W 30 cm CFL lamp has the lowest value of 0.129 A. While the 10W 25 cm LED lamp has the highest current value of 1.138 A. This happens because the power obtained is very low and results in the current in the 5W 30 cm CFL lamp being low as well.

The graph shown in Figure 7(a) illustrates the voltage measurement results produced by 2 different lamp types and 2 different distances. The voltage graph shows that the 5W CFL lamp 25 cm has the lowest voltage value of 1.7141 V. In contrast, the highest voltage is recorded for the 10W LED lamp 30 cm which is 2.7021 V. In contrast, the highest voltage was recorded for the 10W 30 cm LED lamp which was 2.7021 V. This happens because the current produced by the 10W 25 cm LED lamp is higher than the other variations.

The graph shown in Figure 7(b) illustrates the efficiency measurement results. The efficiency graph shows that the 10W 30 cm CFL lamp has the lowest efficiency value of 0.00292%. The highest efficiency was recorded for the 10W 30 cm LED lamp at 0.01169%. This happens because the 10W 30 cm LED lamp has a more stable temperature value. Research on the effect of temperature has been conducted by Dhassa et al. [17] which explains that an increase in photovoltaic temperature causes a decrease in the efficiency of the current (A) and voltage (V) output.

IV. CONCLUSION

The research that has been done regarding 2 types of distances that are varied, namely 25 cm and 30 cm with 2 different types of lamps, namely CFL and LED. In addition, the difference in lamp power, namely 5W and 10 W, shows that increasing the distance between the lamp and the light field results in a decrease in light intensity. This can be seen in CFL lamps with a longer distance between the light source and the solar cell module which results in low light intensity in the 5W 30 cm CFL lamp. The decrease in efficiency in indoor photovoltaic systems affects the temperature and an increase in the temperature of the photovoltaic solar cell causes a decrease in the efficiency of the current (A) and voltage (V) of the electrical output. Further research focuses more on a closer distance to the light source to produce higher light intensity. In addition, if the temperature rises, you can use a cooling method on the indoor photovoltaic.

ACKNOWLEDGMENT

Grateful acknowledgement is given to Universitas Muhammadiyah Surakarta who contributed to the funding of this research through the Tridharma Integration Grant Research scheme with contract number 053/A.3-III/FT/I/2023.

REFERENCES

[1] S. Kouridakis and P. Giakoumakis, “Electronic Device Design for Energy Harvesting of Indoor and Outdoor Light Sources for Multiple Low Power Usage,” *Int. J. Circuits Electron.*, vol. 5, pp. 49–54, 2020,

[2] F. Mateen, M. Ahsan Saeed, J. Won Shim, and S. K. Hong, “Indoor/outdoor light-harvesting by coupling low-cost organic solar cell with a luminescent solar concentrator,” *Sol. Energy*, vol. 207, no. February, pp. 379–387, 2020.

[3] T. Widodo Besar Riyadi, M. Effendy, B. Radiant Utomo, and A. Tri Wijayanta, “Performance of a photovoltaic-thermoelectric generator panel in combination with various solar tracking systems,” *Appl. Therm. Eng.*, vol. 235, no. June, p. 121336, 2023.

[4] M. A. A. Mamun, M. M. Islam, M. Hasanuzzaman, and J. Selvaraj, “Effect of tilt angle on the performance and electrical parameters of a PV module: Comparative indoor and outdoor experimental investigation,” *Energy Built Environ.*, vol. 3, no. 3, pp. 278–290, 2022.

[5] S. Putro, “Pengujian Pembangkit Listrik Tenaga Surya Dengan Posisi Pelat Photovoltaic Horizontal,” *Media Mesin Maj. Tek. Mesin*, vol. 9, no. 1, 2017.

[6] M. Hosenuzzaman, N. A. Rahim, J. Selvaraj, M. Hasanuzzaman, A. B. M. A. Malek, and A. Nahar, “Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation,” *Renew. Sustain. Energy Rev.*, vol. 41, pp. 284–297, 2015.

[7] M. Khairuddin and L. K. Indrawan Nugrahanto, “Investigasi Pengaruh Temperatur Warna Berkorelasi Terhadap Performa Dssc Untuk Sistem Indoor Solar Cell,” vol. 10, no. 1, pp. 74–81, 2021.

[8] B. R. Utomo, I. Isdhianto, H. Kusnanto, M. Iwan, E. Sarwono, and H. K. Hassan, “Analisa Pengaruh Intensitas Cahaya terhadap Kinerja Modul Photovoltaic Cell,” *Creat. Res. Eng.*, vol. 2, no. 2, p. 72, 2022.

[9] A. Venkateswararao, J. K. W. Ho, S. K. So, S. W. Liu, and K. T. Wong, “Device characteristics and material developments of indoor photovoltaic devices,” *Mater. Sci. Eng. R Reports*, vol. 139, no. June 2019, p. 100517, 2020.

[10] H. K. Swarup Biswas, “Optical Simulation Study on Indoor Organic Photovoltaics with Textured Electrodes towards Self-powered Photodetector,” *J. Sens. Sci. Technol.*, vol. 28, no. 4, pp. 236–239, 2019.

[11] A. Al-Dousari, W. Al-Nassar, and M. Ahmed, “Photovoltaic and wind energy: Challenges and solutions in desert regions,” *E3S Web Conf.*, vol. 166, no. May, 2020.

[12] B. R. Utomo, A. Sulistyanto, T. W. B. Riyadi, and A. T. Wijayanta, “Enhanced Performance of Combined Photovoltaic–Thermoelectric Generator and Heat Sink Panels with a Dual-Axis Tracking System,” *Energies*, vol. 16, no. 6, p. 2658, 2023.

[13] S. Tajjour, “SOLAR CELL | Solar cell,” *Www.Britannica.Com*, vol. 4, no. JP2012164733A, pp. 188–191, 2003.

[14] A. I. Soumi, B. R. Utomo, N. T. Atmoko, and E. Sarwono, “Studi Eksperimental Performa Photovoltaic Cell dengan Variasi Jenis Pendingin,” *Creat. Res. Eng.*, vol. 3, no. 2, p. 73, 2023.

[15] R. Peamsuwan, P. Waramit, I. Worapun, B. Krittacom, T. Phoo-Ngernkham, and R. Luampon, “Investigation of tungsten halogen lamp for possible usage as heat source for testing solar collector,” *Energy Built Environ.*, no. February, 2023.

[16] 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.

[17] L. Rudawin, N. Rajabiah, and D. Irawan, “Analisa sistem kerja photovoltaic berdasarkan sudut kemiringan menggunakan monocrystalline dan policrystalline,” *Turbo J. Progr. Stud. Tek. Mesin*, vol. 9, no. 1, pp. 129–137, 2020..

[18] Muchammad and E. Yohana, “Pengaruh Suhu Permukaan Photovoltaic Module 50 Watt Peak Terhadap Daya Keluaran Yang Dihasilkan Menggunakan Reflektor,” *Rotasi*, vol. 12, no. 4, pp. 14–18, 2010, [Online]. Available: http://ejournal.undip.ac.id/index.php/rotasi

[19] B. Utomo, H. Firdaus, Q. Lailiyah, W. S. Ramadhani, and I. Paramudita, “Performance of single-large simulated sunlight for indoor photovoltaic testing,” *AIP Conf. Proc.*, vol. 2403, no. February 2017, 2021.