



# Jurnal Pena Sains

## Jurnal Pendidikan Sains dan Sains Murni

Journal homepage: <https://journal.trunojoyo.ac.id/penasains>



### VISIBLE WAVELENGTH EFFECT ON TEMPERATURE CHANGE IN GREENHOUSE EFFECT: LABORATORY DESIGN

Isnawati<sup>1</sup>, Siti Sriyati<sup>1</sup>, Eka Cahya Prima<sup>1\*</sup>, Riandi<sup>1</sup>

<sup>1</sup> Department of Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia Bandung, 40154, Indonesia  
*ekacahyaprima@upi.edu*

#### ABSTRACT

School internships typically adhere to a standard format, employing basic tools for educational purposes. Among these, the greenhouse effect modelling laboratory, traditionally conducted under direct sunlight, faces challenges due to the variability introduced by cloud cover. This variability limits the ability to study the influence of light wavelength on the greenhouse effect, an aspect not accounted for when using sunlight alone. This research aims to explore the impact of light wavelength on temperature changes within greenhouse effect models. In our methodology, we employed an experimental setup that simulated the greenhouse effect using artificial light sources of varying wavelengths: red (641 nm), orange (592 nm), yellow (586 nm), green (536 nm), and blue (474 nm). The experiment involved monitoring the temperature increase within the model greenhouse under each light condition, thereby isolating the effect of wavelength from other environmental variables. The results revealed a direct correlation between light wavelength and the rate of temperature increase in the greenhouse model. Specifically, longer wavelengths were associated with a quicker rise in temperature, highlighting the significant role of wavelength in the greenhouse effect's efficiency. This study underscores the necessity of incorporating wavelength considerations into greenhouse effect models, particularly in educational settings. By integrating such experiments into school curricula, students can gain a deeper, more nuanced understanding of the greenhouse effect, moving beyond the limitations of traditional sunlight-based experiments.

#### Article Info

##### Article history:

**Received:** August 5, 2023

**Accepted:** March 24, 2024

**Published:** April 28, 2024

##### Keywords:

Greenhouse effect;

Laboratory;

Temperature;

Wavelength

## **Introduction**

The concept of the greenhouse effect dates back to the 1820s when Joseph Fourier proposed that components within the Earth's atmosphere were responsible for the Earth's primary temperature. He studied the historical origins of the glaciers and ice sheets that later covered much of Europe (Letcher, 2018). Several years later, the concept of the greenhouse effect became popular and was studied extensively by various researchers worldwide, from different countries, so that the greenhouse effect became a global issue that is currently being sought to prevent it. The greenhouse effect currently under discussion is the radiation of sunlight waves.

Sunlight, in the form of shortwave radiation, that strikes the Earth is converted into heat, warming the planet. If the Earth were completely deprived of sunlight, life on Earth would be unable to grow or develop (Kweku et al., 2018). However, a different scenario arises when the heat absorbed by the Earth should have been reflected rather than trapped in gases in the Earth's atmosphere, a phenomenon commonly known as the greenhouse effect. Similar to the greenhouse effect, this is a term commonly used to describe the condition in which the Earth is enveloped by gases trapped in its atmosphere, also known as the natural warming process (Besson, De Ambrosio, & Mascheretti, 2010).

The greenhouse effect occurs when solar radiation strikes the Earth's atmosphere, causing gases to become trapped within the Earth's atmosphere (Zhong & Haigh, 2013). Radiation reflected from the Earth's atmosphere is then blocked, trapping heat within the planet. Consequently, the Earth's temperature rises due to the trapped radiation, leading to various effects on life on Earth (Birch, 2014).

The greenhouse effect is a significant contributor to global warming, as it helps to retain some of the planet's heat that would otherwise dissipate from the atmosphere into space (Kurniatun, H. 2013). A research report on greenhouse gases and their influence on global warming highlights this phenomenon. Without the greenhouse effect, the global average temperature would be significantly lower, rendering life as we know it impossible (Kweku et al., 2018).

In addition to the positive outcomes of the greenhouse effect, there are also negative consequences associated with it. Studies indicate that a total of 29% of the sun's energy is reflected

by the atmosphere, 20% is absorbed by atmospheric gases, and only 51% reaches the Earth's surface. Greenhouse gases that can cause greenhouse effects include CO<sub>2</sub>, CH<sub>4</sub>, CFCs, O<sub>3</sub>, and N<sub>2</sub>O (Pratama, 2019). The contribution of each GHG depends on its longevity in the atmosphere and its Global Warming Potential (GWP) value (Mikhaylov, Moiseev, Aleshin, & Burkhardt, 2020). The increased greenhouse effect resulting from anthropogenic greenhouse gas (GHG) emissions has led to global warming since the Industrial Revolution (Xu & Cui, 2021). CO<sub>2</sub> has emerged as a significant concern due to its substantial contribution to the greenhouse effect, accounting for 50% of other greenhouse gases. The effects of increased CO<sub>2</sub> in the atmosphere include rising temperatures, expanding land surfaces, rising sea levels, extreme weather events, and the emergence of various human and animal diseases (Pratama, 2019).

The impacts of the greenhouse effect are increasingly felt worldwide, leading to numerous government initiatives aimed at mitigating these adverse consequences (Orazalin, Ntim, & Malagila, 2023). In response, one strategy being implemented involves fostering heightened environmental awareness among the populace through various campaigns. These campaigns aim to educate the public about the detrimental effects of the greenhouse effect, reaching beyond community settings to encompass educational environments. Within the realm of education, the topic of the greenhouse effect, as part of broader discussions on global warming, has been integrated into the curriculum, specifically in Grade 9 during the second semester (Kemendikbud, 2023). This approach highlights the government's commitment to integrating environmental education at an early stage, ensuring that students are well-informed about the challenges and potential solutions related to the greenhouse effect.

In the learning materials, global warming is also explained at school, covering its meaning, impacts, and even methods to mitigate it. Additionally, a practical exercise on modeling the greenhouse effect is provided. Regarding greenhouse effect practical exercises in schools (Rima, Munandar, & Anggraeni, 2020) state in their research that: first, practical activities on global warming typically utilize a terrarium model to illustrate temperature increases; secondly, previous research has employed greenhouse model concepts to demonstrate the comparative process of temperature rise in global warming; thirdly, in general, the existing practical activities are still

quite simplistic and do not align with students' fundamental competencies as per curriculum requirements, as they fail to effectively model the greenhouse effect.

Based on the study's findings which is conducted by Rima, munandar and anggraeni in the year of 2020, it is evident that the practices conducted in schools remain very conventional and rely on simple tools. Furthermore, practical activities often involve the use of measuring instruments like water thermometers or less precise alcohol thermometers. Modeling the greenhouse effect is typically conducted outdoors, utilizing sunlight, which may pose challenges if the weather is cloudy. Moreover, the use of sunlight in modeling the greenhouse effect fails to address the influence of wavelengths on this phenomenon.

Sunlight is utilized in the greenhouse modeling process, but controlling its wavelength proves challenging as it is contingent on weather conditions. Consequently, there is a need for technology to substitute sunlight with lamps. The wavelength of light plays a crucial role in determining the output of a solar panel across four different colors of light (Sridewi, Suyanto, & Wijaya Kusuma, 2018). Research indicates a temperature variance for all wavelengths entering the greenhouse (Pujol & Fort, 2002), with temperature also significantly impacting wavelength shift. As temperature rises, wavelength shift increases (Shafira, Isnomo, & Imamuddin, 2021), suggesting a reciprocal relationship between wavelength and temperature. Some studies propose replacing sunlight with artificial light in greenhouse modeling endeavors. To facilitate greenhouse practice in schools, a course incorporating lamps emitting different wavelengths was developed for greenhouse modeling.

In schools worldwide, the greenhouse effect is studied in 9th-grade science during the second semester, focusing on global warming. Learning outcomes in science include developing students' abilities to identify interactions between living organisms and their environment, as well as to design pollution prevention and remediation efforts, and address climate change. In the skills section, students enhance their observation, planning, investigation, data processing, and analysis skills, and then report their findings. School materials on global warming comprehensively cover its definition, impacts, and mitigation strategies, allowing students to engage directly in fieldwork, demonstrations, and even modelling of the greenhouse effect.

Taking this into consideration, the aim of this research was to examine the impact of light wavelength on temperature in greenhouse modeling, and the creation of this practical course in schools served as a tangible application of greenhouse modeling. This can serve as a progression of the curriculum implemented in schools.

The sunlight utilized in modeling the greenhouse effect proves challenging to regulate, with its wavelength being dependent on weather conditions, necessitating engineering interventions such as replacing sunlight with lamps. To differentiate the wavelengths emitted by the lamp light, five distinct colors are employed, comprising red with a wavelength of 620-750 nm, yellow with a wavelength of 570-590 nm, blue with a wavelength of 450-495 nm, green with a wavelength of 495-570 nm, and orange with a wavelength of 590-630 nm. To verify if the wavelengths of each light color align with the literature, the AspectraMini application, which can be installed on a smartphone, is utilized.

In a study conducted by Sridewi, Suyanto and Wijaya Kusuma (2018), it was discovered that the wavelength of light correlates with the output power of a solar panel device when using four different colored lamps. Furthermore, in a study by Toni Pujol and Joaquim Fort (2002), it was stated that the temperature varies at each wavelength entering a greenhouse. Temperature also significantly affects wavelength shifts, with higher temperatures resulting in greater wavelength shifts (Shafira et al., 2021).

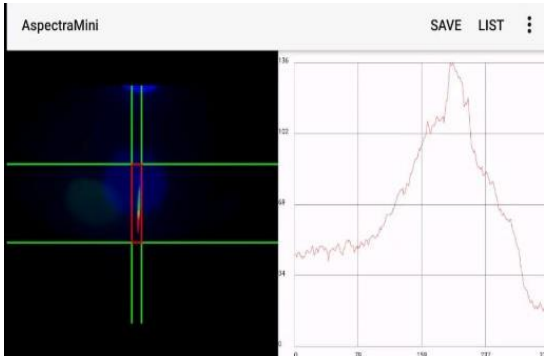
Based on these findings, a hypothesis can be formulated that demonstrates the influence of long wavelengths on the greenhouse effect, as evidenced by the temperature increase observed during greenhouse effect simulations.

## **Research Methods**

The research method employed in the study was an experiment conducted at the IPSE Physics Laboratory. The tools and materials utilized include: 1 plastic box, sufficient soil, 1 Philips smart Wi-Fi LED lamp (with 5 available colors of light, namely red, blue, yellow, green, and orange), 1 thermocouple, stopwatch, and a cellphone with the Wiz application installed and connected, which had previously been linked to the lamp.

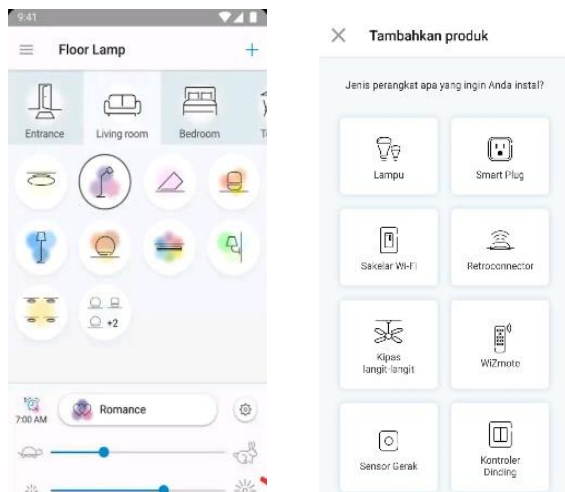
The experiments conducted consisted of two steps, the first step is the Pre-experiment Activity. Before conducting the experiments, pre-

experiments were carried out initially. These pre-experiments were conducted to measure the wavelength of the lamp colors that would be utilized in the study. In this pre-experiment activity, the AspectraMini application 1.0.8 version by Jandro Tek, which had been installed on a cell phone, was employed. This application is user-friendly and capable of measuring the wavelength of light, as seen in the Figure 1.



**Figure 1.** Aspectramina display used in pre-experimental data collection

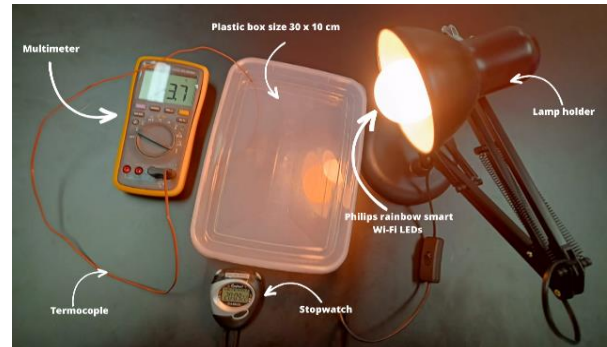
The lamp used in this test is a Philips Smart Wi-Fi LED Rainbow Lamp. This Philips lamp can be connected to your mobile phone via the Wiz application 1.29.0 version by signify Netherlands B.V. The purpose of the researcher using this lamp is to be able to use the Wiz application to add color to the lamp and push out the color of the lamp used in this study. By using a characteristic color of light, the emitted wavelength is routinely characteristic. A view of the wiz application is shown in Figure 2.



**Figure 2.** Wiz application

The second step takes the form of experimental activities. These activities are conducted in a laboratory with a constant

temperature to ensure that it does not affect the temperature increase results. The procedure for this experiment involves preparing the necessary tools and materials. Next, fill the plastic box with soil and insert the thermocouple rod into the box, then seal the plastic box. Subsequently, place the box in a dark location, turn on the red light, and direct the light toward the box. Monitor the temperature readings on the thermocouple every 5 minutes for 2 hours, repeating this process for each color of the lamp. The arrangement of the tools can be seen in Figure 3.



**Picture 3.** The greenhouse effect modeling tool used during the research

Five different colors with different wavelengths were used to distinguish the obtained wavelengths. That is, red with a wavelength of 620-750 nm, yellow with a wavelength of 570-590 nm, blue with a wavelength of 450-495 nm, and green with a wavelength of 570-590 Nm. 495-570 Nm with wavelengths 590-630 and orange. The wavelengths of these recorded lights were obtained from the literature.

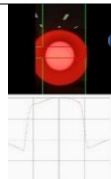
The Aspectramini and Wiz applications, which can be easily installed on mobile phones, allow students to bring this technology to greenhouse experiments.

## Result and Discussion

### Pra-experiment

The results of the experimental practice activities can be seen in Table 1.

**Table 1.** Wavelength

No	Color	Wavelength	
		AspectraMini	Literatur
1	Red		the part of the visible spectrum that has a wavelength

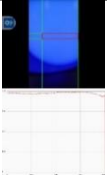
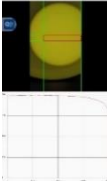
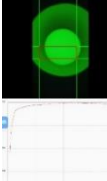

		The visible wavelength is 641 nm.	between 630-700 nm.
2	Blue		the part of the visible spectrum that has a wavelength between 450-480 nm.
		The visible wavelength is 474 nm	
3	Yellow		the part of the visible spectrum that has a wavelength between 560-590 nm.
		The visible wavelength is 586 nm	
4	Green		the part of the visible spectrum that has a wavelength between 480-560 nm.
		The visible wavelength is 536 nm	
5	Orange		the part of the visible spectrum that has a wavelength between 590-630 nm.
		The visible wavelength is 592 nm	



Figure 4. Observe the wavelength

From the pre-check results, it could be visible that the wavelengths produced in every lamp shadeation healthy the literature. so that it could be used in this study.

Experiment

In this study, the lamp colors used were red, yellow, blue, green, and orange, and the maximum wavelengths were based on results of 641 nm, 474 nm, 586 nm, 536 nm, and 592 nm, respectively. previous experiment. Observations were made in a dark room with a constant temperature of 24.4 °C to make the data generated by the lamp more valuable. Also, the reason for using the same ambient temperature for each lamp is so that you can more clearly see the temperature rise that each lamp experiences. Observations were made in a dark room, so other lights did not affect temperature changes in this experiment. We expect the temperature changes obtained in the experimental results to be due only to the light directed at the greenhouse model box.

Light observations were made by directing the light at a model greenhouse box containing soil and thermocouple rods. Thermocouple readings are checked every 5 minutes for 2 hours. This is done for each lamp. The result from this observation is that there is an increase in temperature for each color of light but not for each color. This can be seen in Figure 5.

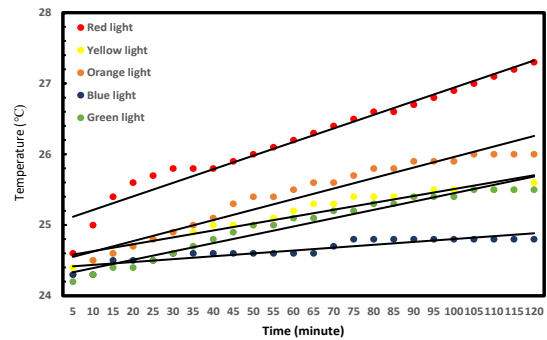


Figure 5. Temperature comparison with the color of the light

The results show that the temperature of each light color varies greatly between lamp colors. Figure 1 shows that blue light colors heat up more slowly than other light colors. The color of light with a faster temperature rise is the color of red light. However, for orange, yellow, and green lights, the temperature rise is relatively steady.

Table 2. Effect of wavelength on temperature rise

Light color	$\Delta T$	$\Delta T/\Delta t$	R
Red ( $\lambda=641$ )	2.9	0.024166667	0.9784
Orange ( $\lambda=592$ )	1.6	0.013333333	0.9716

Yellow ( $\lambda=586$ )	1.2	0.01	0.9684
Green ( $\lambda=536$ )	1.1	0.009166667	0.9775
Blue ( $\lambda=474$ )	0.4	0.003333333	0.9181

Red light has a longer wavelength than other colors such as orange, yellow and green. Based on table 1 it can be seen that the average increase in temperature for each color of light is different. Lamps with higher wavelengths have a faster temperature increase. In this experiment, it can be seen that the red light with a wavelength of 641 nm has a temperature change of 2.9 C, while the blue lights with a wavelength of 474 nm experience the slowest increase in temperature, namely 0.4 C. Based on these results it can be said that the wavelength of light is directly proportional to the temperature in the modeling of the greenhouse effect, the higher the wavelength of light directed at modeling the greenhouse effect, the faster the temperature increases, this can be seen in figure 6.

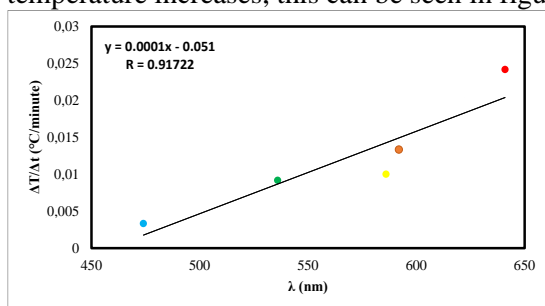


Figure 6. Effect of wavelength on temperature rise

The results of the experiment demonstrated a clear correlation between light wavelength and the rate of temperature increase in the greenhouse model. Notably, longer wavelengths were associated with a more rapid rise in temperature. This is in line with research conducted by Riswanto, Junus and Isnomo in 2020 which states that the higher the temperature, the farther the wavelength shift of light. This finding emphasizes the significant role of wavelength in determining the efficiency of the greenhouse effect.

Traditionally, greenhouse effect modeling laboratories rely on sunlight, which poses limitations due to its variability caused by cloud cover. As research conducted by Rima et al in 2020, states that the greenhouse effect modeling that has been done so far is less effective due to many factors that influence it, one of which is erratic sunlight. This variability hampers the ability to study the influence of light wavelength on the greenhouse effect accurately. By utilizing artificial light sources with controlled wavelengths, this study overcomes these limitations and provides valuable insights into the relationship between

light wavelength and temperature changes in greenhouse environments.

These findings underscore the importance of incorporating wavelength considerations into greenhouse effect models, particularly in educational settings. By integrating such experiments into school curricula, students can gain a deeper understanding of the greenhouse effect, moving beyond the constraints of traditional sunlight-based experiments. Moreover, this approach enhances students' ability to comprehend the complexities of environmental processes and fosters a more comprehensive understanding of climate change phenomena.

## Conclusion

Based on the experimental results conducted, it can be concluded that light wavelength significantly influences temperature. Specifically, the longer the wavelength, the faster the temperature rises in modeling the greenhouse effect. Consequently, the development of a greenhouse effect modeling practicum supported by lighting can enhance students' time efficiency and utilize technology, resulting in more precise outcomes. This laboratory course's development could also serve as an educational tool in schools to aid students' understanding of the greenhouse effect.

## Acknowledgment

The assistance provided by the IPSE laboratory as a place for this research was invaluable. The authors would also like to thank the supervisors who have helped evaluate this work before it was submitted for publication and (1) Balai Pembiayaan Pendidikan Tinggi (Center of Higher Education Fund) – BPPT, The Ministry of Education, Culture, Research, and Technology, Republic of Indonesia, and (2) Lembaga Pengelola Dana Pendidikan (Indonesia Endowment Fund for Education) LPDP, Ministry of Finance Indonesia for granting a scholarship to the first author and the presenter to complete his study.

## References

Besson, U., De Ambrosis, A., & Mascheretti, P. (2010). Studying the physical basis of global warming: Thermal effects of the interaction between radiation and matter and greenhouse effect. *European Journal of Physics*, 31(2),

375–388. <https://doi.org/10.1088/0143-0807/31/2/015>

107(21), ACL 5-1-ACL 5-7. <https://doi.org/10.1029/2001JD001578>

- Birch, E. L. (2014). A Review of “Climate Change 2014: Impacts, Adaptation, and Vulnerability” and “Climate Change 2014: Mitigation of Climate Change.” *Journal of the American Planning Association*, 80(2), 184–185. <https://doi.org/10.1080/01944363.2014.954464>
- Kurniatun, H. (2013). PERUBAHAN IKLIM GLOBAL: Penyebab dan dampaknya terhadap lingkungan dan kehidupan Kurniatun Hairiah. *Tanah, Jurusan Pertanian, Fakultas Brawijaya, Universitas Veteran, Jl*, (perubahan iklim), 1–41.
- Kweku, D., Bismark, O., Maxwell, A., Desmond, K., Danso, K., Oti-Mensah, E., ... Adormaa, B. (2018). Greenhouse Effect: Greenhouse Gases and Their Impact on Global Warming. *Journal of Scientific Research and Reports*, 17(6), 1–9. <https://doi.org/10.9734/jsrr/2017/39630>
- Letcher, T. M. (2018). Why do we have global warming? In *Managing Global Warming: An Interface of Technology and Human Issues*. Elsevier Inc. <https://doi.org/10.1016/B978-0-12-814104-5.00001-6>
- Mikhaylov, A., Moiseev, N., Aleshin, K., & Burkhardt, T. (2020). Global climate change and greenhouse effect. *Entrepreneurship and Sustainability Issues*, 7(4), 2897–2913. [https://doi.org/10.9770/jesi.2020.7.4\(21\)](https://doi.org/10.9770/jesi.2020.7.4(21))
- Orazalin, N. S., Ntim, C. G., & Malagila, J. K. (2023). Board Sustainability Committees, Climate Change Initiatives, Carbon Performance, and Market Value. *British Journal of Management*, 35, 295–320. <https://doi.org/10.1111/1467-8551.12715>
- Pratama, R. (2019). Efek Rumah Kaca Terhadap Bumi. *Buletin Utama Teknik*, 14(2), 1410–4520.
- Pujol, T., & Fort, J. (2002). The effect of atmospheric absorption of sunlight on the runaway greenhouse point. *Journal of Geophysical Research Atmospheres*,
- Rima, R., Munandar, A., & Anggraeni, S. (2020). Pengembangan kegiatan praktikum pemodelan efek rumah kaca untuk siswa SMA pada materi perubahan lingkungan. *Assimilation: Indonesian Journal of Biology Education*, 3(1), 34–38. <https://doi.org/10.17509/aijbe.v3i1.23308>
- Riswanto, M. A., Junus, M., & Isnomo, Y. H. P. (2020). Analisis Perubahan Suhu Terhadap Panjang Gelombang Pada Media Fiber Optik Berstruktur Singlemode-Multimode. *Jurnal Jartel: Jurnal Jaringan Telekomunikasi*, 10(3), 129–135. <https://doi.org/10.33795/jartel.v10i3.103>
- Shafira, A. D., Isnomo, Y. H. P., & Imamuddin, A. M. (2021). Pengaruh Perubahan Suhu terhadap Nilai Panjang Gelombang Fiber Optik yang Difungsikan Sebagai Sensor Suhu. *Jurnal Jartel: Jurnal Jaringan Telekomunikasi*, 11(1), 17–22. <https://doi.org/10.33795/jartel.v11i1.104>
- Sridewi, N. L. P. M., Suyanto, H., & Wijaya Kusuma, I. G. B. (2018). Analisis pengaruh panjang gelombang cahaya terhadap keluaran panel surya tipe polycrystalline. *Jurnal METTEK*, 4(2), 48. <https://doi.org/10.24843/mettek.2018.v04.i02.p03>
- Xu, Y., & Cui, G. (2021). Influence of spectral characteristics of the Earth’s surface radiation on the greenhouse effect: Principles and mechanisms. *Atmospheric Environment*, 244(516), 117908. <https://doi.org/10.1016/j.atmosenv.2020.117908>
- Zhong, W., & Haigh, J. D. (2013). The greenhouse effect and carbon dioxide. *Weather*, 68(4), 100–105. <https://doi.org/10.1002/wea.2072>