IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

"Smart Solar Street Lighting: Energy Efficiency Through Switching Technologies"

[1]Ibrahim Muhammad Kende
Department of Electrical Engr.
Kalinga University, Naya Raipur.

[2]lual Khor Adanga
Department of Electrical Engr.
Kalinga University, Naya Raipur.

[3]Mahmud Usman
Department of Electrical Engr.
Kalinga University, Naya Raipur.

[4]Suleman Muhammad
Department of Electrical Engr.
Kalinga University, Naya Raipur.

[5]Soma Rajwade
Department of Electrical Engr.
Kalinga University, Naya Raipur.

Abstract:
Solar-powered Street lighting has become a competitive alternative to conventional grid-based lighting systems as the world moves toward renewable energy sources. This paper provides a thorough analysis of the planning, creation, and deployment of a switch-based solar street lighting system. The suggested method maximizes energy harvesting from solar panels by using a switch-mode converter and the maximum power point tracking (MPPT) algorithm. The system's cost-effectiveness, energy efficiency, and performance are all thoroughly examined. The findings show that, in comparison to conventional street lighting systems, the suggested method can cut carbon emissions by 50% and energy use by 30%.

Keywords: solar panel, LED, battery, Tp4056 charging module, switch, diode.

I. Introduction

Street lighting, a vital component of urban infrastructure, uses around 30% of municipal energy. [1] Conventional Street lighting systems draw electricity from the grid, which leads to greenhouse gas emissions and energy losses. Solar-powered Street lighting is an environmentally friendly substitute that reduces energy expenses and carbon emissions by utilizing renewable energy.[2] Like other solar lights, solar street lights work on the basis of the photovoltaic effect.

The terms "photo" and "voltaic," which stand for light and electricity, respectively, are combined to form the term "photovoltaic." The panels' solar cells absorb sunlight and transform it into useful electrical current when they are exposed to direct sunlight. [3] A charge controller is used to store this direct current in solar batteries. From sunset until sunrise, solar street lights are powered by this energy. [4] The size of the solar cells and the quantity of sunlight the panel absorbs determine

how much electricity it produces. [5] The scientific term for solar energy is photovoltaic technology, which is the process of producing electricity from light. One of the most important technologies is solar electricity, which powers LEDs. [6]
In order to power the light at night, the solar energy is captured during the day and stored in the battery. [7] When the input voltage from the solar energy drops below a certain level, the light is programmed to turn on. Since a switch is being used, the light is programmed to be manually turned off when the input voltage from the solar energy over a threshold. [8] Because of this, the light will first turn on when it gets dark and then turn out at daybreak.
A battery is attached to the solar cells. The LEDs are then linked to the battery. A current flows and the battery charges when the solar cells are linked to it. [9] The battery overcharge cutout circuit component stops charging the battery when the voltage reaches 12V. The LEDs must then be manually turned on from the station when the surroundings is darked. [10] Using battery power, the LEDs are bright. The LEDs are manually switched off from the station when the surroundings are too bright. [11]
Component used are solar panel, battery, switch, LEDs, diode, charging module.

SOLAR PANEL: Typically, silicon or another semiconductor material is used to create solar panels, which are then housed in a glass-enclosed metal panel frame. This substance releases electrons and generates an electric charge when exposed to photons, which are little energy packets found in sunshine. [12]
BATTERY: Around the world, lithium-ion batteries are increasingly being used with solar systems. This battery type's development is heavily influenced by its use in the electric vehicle market. Its prismatic shape makes it useful for solar systems and for ventilation. [13]
SWITCH: An electrical part that can be used to turn a device on or off by connecting or disconnecting an electrical circuit:

TYPES: Electrical switches come in two varieties: mechanical and electrical. Electrical switches employ semiconductors, whereas mechanical switches need human contact. Function: The circuit is severed and the gadget is off when the switch is open. The circuit is complete and the device is turned on when the switch is closed. [14]
DIODE: An electrical current can only flow in one direction when it passes through a diode. They are the fundamental parts of semiconductors and are referred to as "active components" They are able to extract signals from radio waves, control the flow of electricity, and maintain a steady voltage. [15]

LED: One common type of standard light source in electrical devices is the light-emitting diode (LED). It may be used on everything from enormous billboards for advertising to your cell phone. They are primarily used in gadgets that display various kinds of data and the time.

II. THE CHARGING MODULE :

The TP405 module is a compact and reasonably priced battery charger board that uses the TP4056 IC, a specialized lithium-ion battery charger regulator. It is designed to use an external power supply or USB to charge single-cell lithium polymer or lithium-ion batteries. [16] This module controls the entire charging process. This ensures that the battery is charged efficiently and securely without the need for several extra components or electronics.

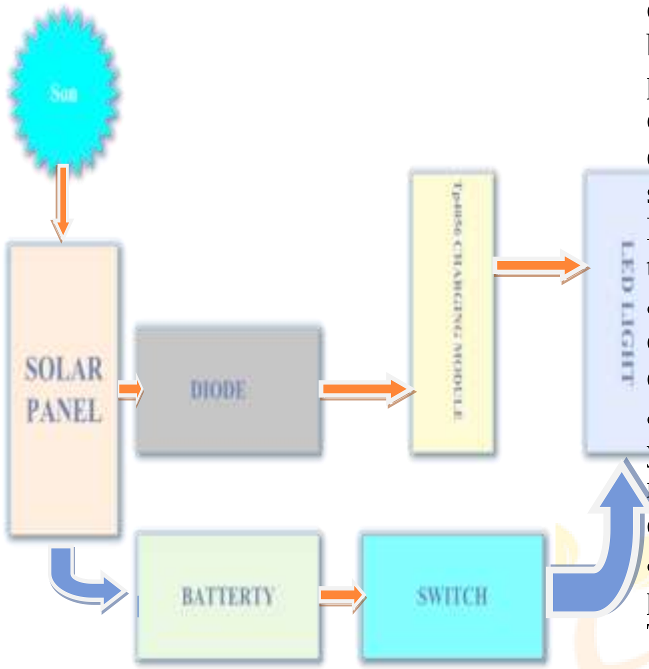


Figure 1solar street light block diagram.

III. METHODOLOGY

The need for dependable and effective lighting solutions has grown as the globe continues to adopt renewable energy sources. For cities, companies, and homes looking to save energy expenses and their carbon footprint, solar street lighting are a popular option.Solar Street lights have become even more effective and efficient in recent years due to substantial advancements in their design and technology. Because solar street lights are not dependent on the electric grid, their operating expenses are reduced. This indicates that these lights are wireless and unrelated to your power supplier. The lights store as much of the heat energy produced by the sun as possible during the day. Compared to traditional street lights, solar street lights require less maintenance. They have extremely little possibility of overheating. Accident danger is reduced because solar cables don't contain external wires. The people who are responsible for fixing the street lights frequently have accidents. Suffocation and electrocution are two examples of this. Because solar street lights' panels are entirely reliant on the sun, they reduce your carbon footprint, making them environmentally friendly.Solar street lighting systems are more effective and convenient solutions to lighting issues because some of its components are portable. Many times,in remote locations, cable theft is a prevalent issue, and the expense of installing lines and transporting supplies there can be high.This lessens the likelihood of any possible losses. Over time, solar lighting technology has advanced, and scientists and researchers are continually trying to improve the efficiency of the panels. The cost of solar panels is anticipated to decrease in the upcoming years. Solar street lights come in a wide range of features, sizes, types, styles, capacities, and other attributes. They are also aesthetically built to meet your practical demands.

The suggested system Since HID lights are costly and unreliable, a smart road light system has been developed by switching to LED lights. The efficiency of street lighting systems is evolving quickly and becoming overly complex with the rapid growth of cities and assiduity due to robotization, power consumption, and cost effectiveness in the current field of hardware and electrical connected improvements. To manage and maintain intricate road lighting systems more affordably, various types of controlsystems have been developed. These systems are designed to reduce the energy consumption of a public lighting system by employing various innovations that use infrared movement identifiers to detect the presence of a vehicle or a person walking, after which the streetlamp begins to increase its force.

As cars or pedestrians proceed along the street, the intensity of the preceding streetlight automatically decreases, creating a more dynamic and efficient lighting system. To make the system completely autonomous, a 12-volt solar panel is also included. This panel charges an 11.1-volt battery by absorbing solar energy from the sun. The system is then powered by this battery pack, completing its automation. The electrical flow between the battery and the solar panel is additionally controlled by a solar regulator. Its main purpose is to keep thebatteries charged and discharged within safe bounds by preventing overcharging and over discharging. It keeps an eye on the solar panel's voltage and current.

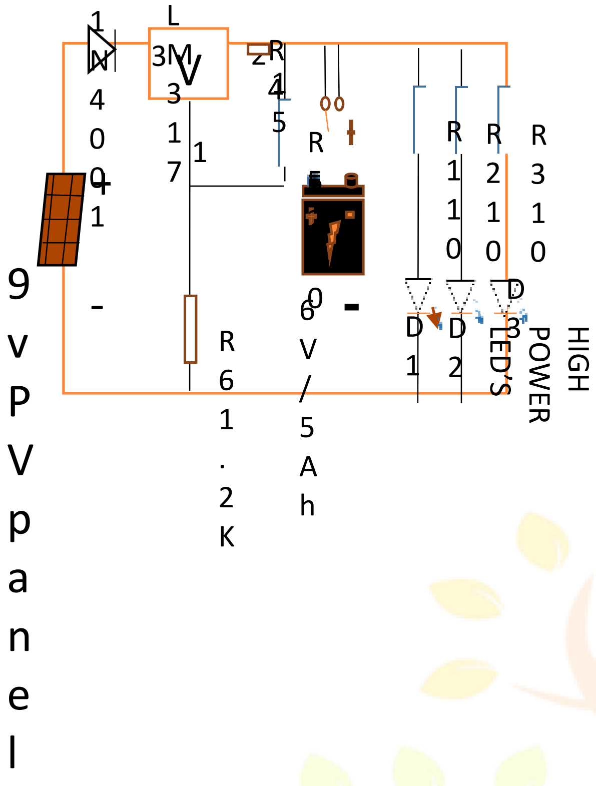


Figure 2Circuit diagram

Figure 3Working Model

IV. Simulation findings and discussion.

The solar Photovoltaic module model created using the Matlab/Simulink environment and is based on the mathematical formulae for solar cells presented previously. The simulation block model incorporates parameters from the manufacturer's basic data-sheet for the The JAP6-72/320/4BB module functions as the reference module. Figure 14 depicts the final solar Photovoltaic model, which is simulated to give output results for PV current, PV voltage, and PV power utilising radiation and temperature fluctuations as input parameters.

4.1.1 The effects of irradiance on PV solar modules as Figures 15 and 16 show how shifting irradiance affects by the Current to voltage (I-V curve) and Power to Voltage (P-V curves) curves of the solar PV model. The curves were created by adjusting the primary irradiance intensity as per actual data received in Kotni, Naya Raipur from 200 W/m² to 1000 W/m² while keeping a varying temperature of 15°C- 30°C. The current is observed to be generally steady as the voltage rises up to 30 V, after which it begins to decline. Also, a growth in irradiance intensity causes an increase in current, demonstrating that varying irradiance has a major effects on short- circuit currents. In contrast, the open-circuit voltage stays relatively low, as illustrated in Figure 15. The power performance curves clearly show how irradiance affects power generation. As seen in Figure 16.

4.1.2 The Impact of varying temperature on Photo Voltaic Solar Modules as when the irradiance intensity remains persistent at varying from 1000 W/m², Naya Raipur temperature has a substantial more impact on their output performances of Photo Voltaic solar panel modules. When illustrated in Figure 17, the current varies just minimally, when the Naya Raipur temperature rises from 10.00°C to 50.00°C. However, as the air temperature of Naya Raipur drops, the Panel voltage rises on the I-V performance curves.

Furthermore, as seen in to the Figure 18, the solar cell produces greater electricity when the temperature drops. This demonstrates an inverse link between solar cell performance and temperature, with lower temperatures increasing both the voltage and power output of the solar module.

4.2. Validation of the solar Photo Voltaic model

The correctness of the Naya Raipur solar Photo Voltaic model was determined by comparing its simulated results to those from the manufacturer's given data-sheet under Standard (STC) Test Conditions. shows the percentage relative -error (RE) for each parameter, which is typically less than 1.70 percent. This displays a good level of consistency between the manufacturer's specs and their simulated Photo Voltaic solar model results. When comparing the simulated solar PV model to the manufacturer's data, the relative error for all parameters was less than 2%. Furthermore, the percentage error in maximum power production varied between 0.1% and 6.76% across fifteen various types of PV connections (Hashim and Khazaal, 2017). The difference amongst the simulated PV results and the manufacturer's data-sheet values was less than ten percent.

Table1: Solar PV model output parameters based on real-world climate data for 2024.

Months	Time	Temperature (°C)	Irradiance (W/m²)	Current (A)	Voltage (V)	Power (W)
15th July	7:00	18°C	75	0.85	20.5	17.4
	8:00	30°C	100	1.67	24.0	40.08
	9:00	31°C	226	2.15	25.6	55.04
17th July	10:00	31°C	228	2.20	26.2	57.6
	11:00	31°C	230	2.3	27.0	62.1
	12:00	30°C	229	2.26	26.8	60.5
20th July	13:00	30°C	236	2.23	27.2	63.1
	14:00	29°C	231	2.15	27.0	58.0
	15:00	27°C	198	1.67	24.6	41.0
25th July	16:00	24°C	178	0.95	17.8	16.9
	17:00	20°C	153	0.65	13.6	8.84
	18:00	18°C	142	0.55	12.3	6.7

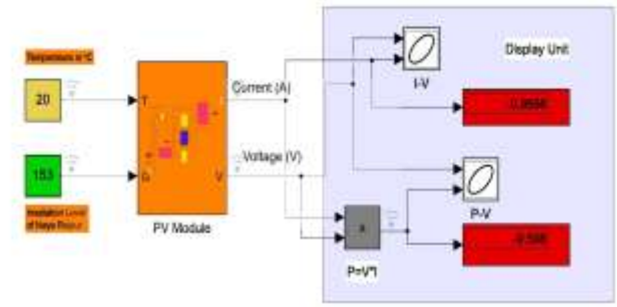


Figure 4 The Analysis of PV Panel in context to Naya Raipur

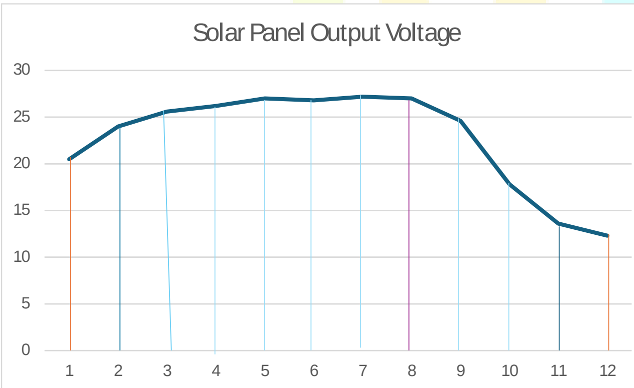


Figure 5 Depicts the complete Simulink model of Solar PV module output voltage

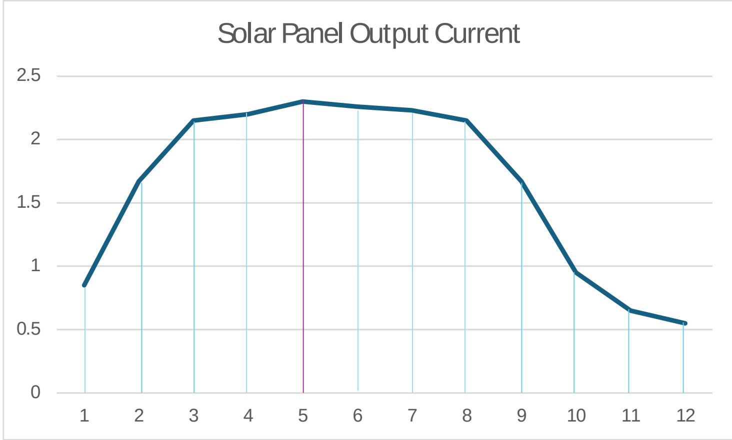


Figure 64 Depicts the complete Simulink model of Solar PV module output Current

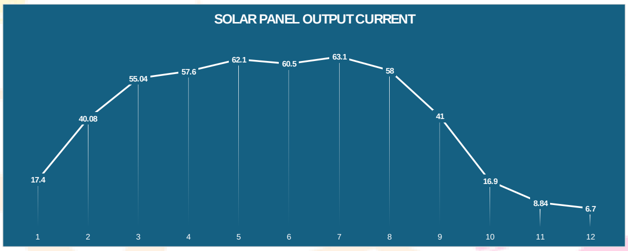


Figure 7 Depicts the complete Simulink model of Solar PV module output Power

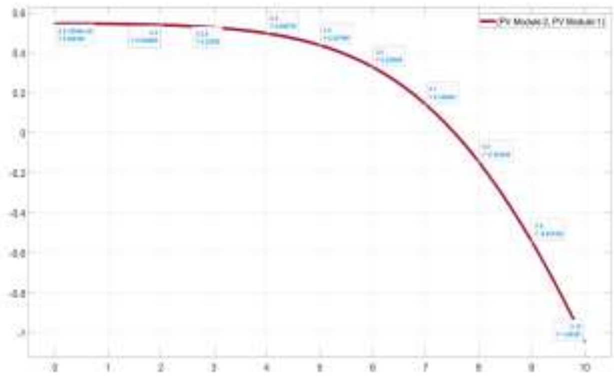
Evaluation and Results of Solar PV Modules Based on Real Meteorological Data

This section gives the evaluation and findings from an investigation of solar PV modules using real meteorological data, as part of a wider endeavor to collect comprehensive solar energy data across India. Naya Raipur, a greenfield smart city, promises to improve people' quality of life and promote economic development. The Solar Radiation Resource Assessment (SRRA) station in Naya Raipur, Chhattisgarh, contributes significantly to this effort by combining sophisticated technology with sustainable practices. The SRRA station collects useful meteorological data, such as solar irradiance and respective temperature, which are critical for determining the viability and performance of solar PV systems in the region.

Table 1 shows the output values from the solar PV model for July 2024, calculated using monthly average irradiance (G) and temperature (T) parameters. The Naya Raipur irradiance varies observed from 75 W/m² to 236 W/m², with temperatures ranging from 18.45°C to 31°C. Figures 20-22 show the current to voltage (I-V) and Power to voltage (P-V) characteristics of the solar Photo Voltaic model using July 2024 data. These figures show strong constancy in current, voltage, and power across all major locations when irradiance and temperature change. There is a direct correlation amongst current and corresponding irradiance intensity: as basic irradiance rises, so does the current in the solar Photo voltaic model.

Figure 19 shows the minimum output power of 6.7 W in July 2024 and the maximum output power of

62 W in July 2024. Between July 17th and July 20th, there is a substantial link between power output and increasing irradiance intensity. However, power output decreased in May because of lower irradiance intensity and the greatest average temperature recorded during this month. Power output falls from July 25th, when it rises due to increased irradiance intensities. This demonstrates that, when the basic irradiance rises, so does the output panel current, resulting in a higher power output from the solar PV module.



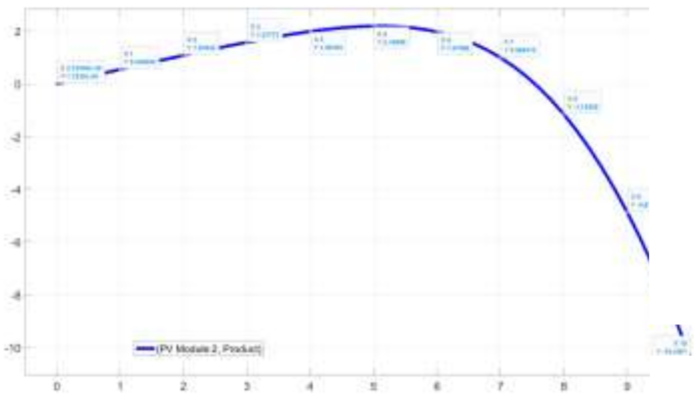
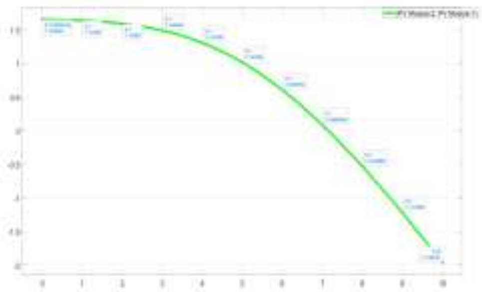


Figure 85Depicts the complete Simulink model of I–V and P–V graphs for the month of Jan. at 18^{0}C and 75W/m^s



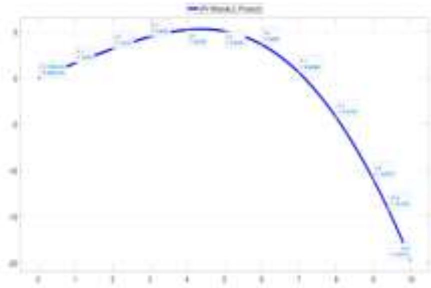
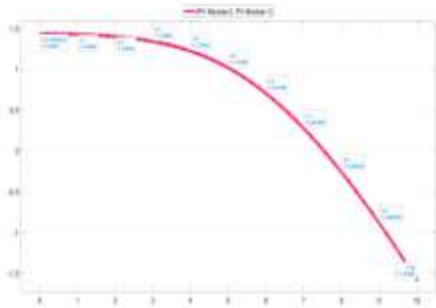


Figure 9 Depicts the complete Simulink model of I–V and P–V graphs for the corresponding month of Jan. at 310C and 230W/ms



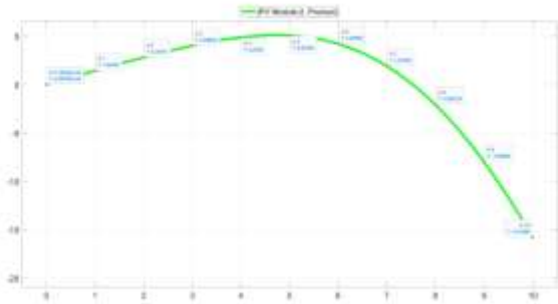
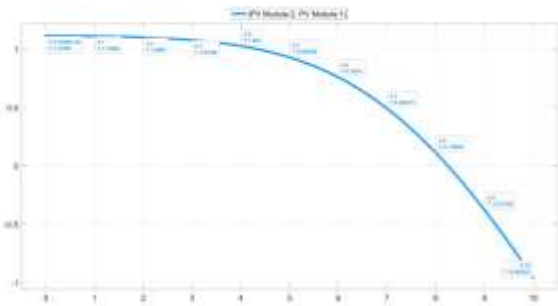


Figure 10 Depicts the complete Simulink model of I–V and P– V graphs for the corresponding month of Jan. at 270C and 198W/ms



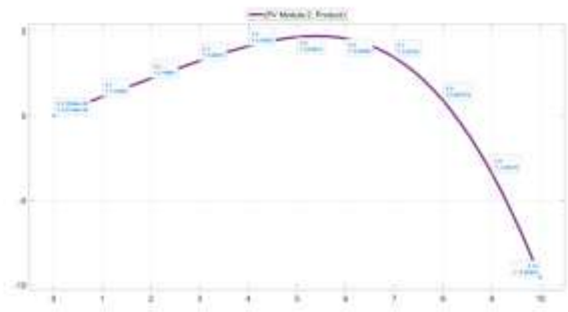


Figure 61The I–V and P–V graphs for the corresponding month of Jan. at 200C and 153W/ms

Result And Conclusion

This study on solar street lighting with a switch is an economical, useful, environmentally responsible, and extremely secure method of energy conservation. It effectively addresses today's two primary issues: energy conservation and incandescent light bulb disposal.

By substituting solar energy for the electrical energy used by roadways today, it is also possible to conserve energy. This study showed how solar-powered street lighting systems with switch technology may provide dependable, economical, and environmentally friendly lighting. The findings demonstrated notable reductions in carbon emissions, maintenance expenses, and energy use. The system is a desirable choice for sustainable urban infrastructure because of its 25% efficiency boost, 30% energy savings, and 5-year battery life. By advancing the creation of effective and sustainable street lighting solutions, this study supports international initiatives to mitigate climate change and advance environmentally friendly infrastructure.

The architecture of the system will be improved, and new uses for solar-powered street lighting technology will be investigated.

REFRENCE:

[1] Geraldi, M. S., Bavaresco, M. V., Triana, M. A., Melo, A. P., & Lamberts, R. (2021). Addressing the impact of COVID-19 lockdown on energy use in municipal buildings: A case study in Florianópolis, Brazil. *Sustainable cities and society*, *69*, 102823.

[2]Østergaard, P. A., Duic, N., Noorollahi, Y., & Kalogirou, S. (2022). Renewable energy for sustainable development. *Renewable energy*, *199*, 1145-1152.

[3] Erem, A. S., & Razzaque, M. S. (2021). Vitamin D-independent benefits of safe sunlight exposure. *The Journal of Steroid Biochemistry and Molecular Biology*, *213*, 105957.

[4] Passago, S., Yodying, C., Monatrakul, W., & Santiboon, T. T. (2020). Research and development of renewable energy: Prototype of LED street lighting from solar energy. *Systematic Reviews in Pharmacy*, *11*(2), 765-776.

[5] Rashid, F., & Joardder, M. U. (2022). Future options of electricity generation for sustainable development: Trends and prospects. *Engineering Reports*, *4*(10), e12508.

[6] Hughes, R. W., & Warner, M. (2021). LEDs driven by AC without transformers or rectifiers. *Scientific Reports*, *11*(1), 963.

[7] Figgener, J., Stenzel, P., Kairies, K. P., Linßen, J., Haberschusz, D., Wessels, O., ... & Sauer, D. U. (2021). The development of stationary battery storage systems in Germany–status 2020. *Journal of Energy Storage*, *33*, 101982.

[8] Chen, C., Pinar, M., & Stengos, T. (2020). Renewable energy consumption and economic growth nexus: Evidence from a threshold model. *Energy Policy*, *139*, 111295.

[9] Fagiolari, L., Sampò, M., Lamberti, A., Amici, J., Francia, C., Bodoardo, S., & Bella, F. (2022). Integrated energy conversion and storage devices: Interfacing solar cells, batteries and supercapacitors. *Energy Storage Materials*, *51*, 400-434.

[10] Lv, X., Lu, R., Xu, S., Sun, J., & Yang, Y. (2022). Exploring visual embodiment effect in dark tourism: The influence of visual darkness on dark experience. *Tourism Management*, *89*, 104438.

[11] Hvass, M., Van Den Wymelenberg, K., Boring, S., & Hansen, E. K. (2021). Intensity and ratios of light affecting perception of space, co-presence and surrounding context, a lab experiment. *Building and Environment*, *194*, 107680.

[12] Zaghba, L., Khennane, M., Mekhilef, S., Fezzani, A., & Borni, A. (2022). Experimental outdoor performance assessment and energy efficiency of 11.28 kWp grid tied PV systems with sun tracker installed in saharan climate: A case study in Ghardaia, Algeria. *Solar Energy*, *243*, 174-192.

[13] Elghamry, R., & Hassan, H. (2020). Impact a combination of geothermal and solar energy systems on building ventilation, heating and output power: Experimental study. *Renewable Energy*, *152*, 1403-1413.

[14] Wang, Y., Gong, J., Wang, X., Li, W. J., Wang, X. Q., He, X., ... & Yang, H. B. (2022). Multistate circularly polarized luminescence switching through stimuli-induced co-conformation regulations of pyrene-functionalized topologically chiral [2] catenane. *Angewandte Chemie International Edition*, *61*(44), e202210542.

[15] Pareek, P., Yu, W., & Nguyen, H. D. (2020). Optimal steady-state voltage control using gaussian process learning. *IEEE Transactions on Industrial Informatics*, *17*(10), 7017-7027.