



ORIGINAL RESEARCH ARTICLE

DEVELOPMENT OF SMART ENERGY-EFFICIENT LIGHTING SYSTEM USING AC-TIED SOLAR PV WITH LIGHT SENSITIVITY CONTROL.

S. O. Omogoye<sup>1</sup>, A. B. Ogundare<sup>1</sup>, A. A. Yekinni<sup>2</sup>, M. A. Adedoyin<sup>3</sup>, J. B. Oyetola<sup>1</sup>, G. P. Ogunyemi<sup>1</sup>, H. Q. Olalekan<sup>1</sup>

<sup>1</sup>Electrical and Electronic Engineering Department, Lagos State University of Science and Technology, Ikorodu, Lagos, Nigeria.

<sup>2</sup>Mechanical Engineering Department, Lagos State University of Science and Technology, Ikorodu, Lagos, Nigeria.

<sup>3</sup>Electronic and Computer Engineering Department, Lagos State University, Ojo, Lagos.

Corresponding author's email: [omogoye.s@lasustech.edu.ng](mailto:omogoye.s@lasustech.edu.ng)

ARTICLE INFORMATION

Received: 10<sup>th</sup> May 2025

Revised: 9<sup>th</sup> July 2025

Accepted: 12<sup>th</sup> July 2025

Keywords:

AC-Tied Solar PV

Energy-efficient lighting

Light sensitivity control

Smart lighting system

ABSTRACT

Unreliable power supply from utility companies in Nigeria undermines the ability of universities to provide quality services, particularly disrupting critical night-time security operations. A persistent issue at Lagos State University of Science and Technology (LASUSTECH), Ikorodu Lagos State is the pervasive darkness during utility load shedding, which directly hinders security personnel. Current solutions like using diesel generators (DGs), hybrid renewable energy supply systems (HRESS), and standalone renewable energy supply systems (SRESS) present significant drawbacks: in addition, DGs are expensive to run while HRESS require substantial upfront investment. Similarly, SRESS used for street lighting, leave many campus areas such as the walkways, offices, and classrooms in darkness at night. To address these shortcomings and enhance night-time security, this research proposes an improved alternating circuit (AC)-tied Solar-photovoltaic (PV)-based lighting system (IACSLS). This research involved systematic modeling, design, simulation, construction, and implementation of the proposed IACSLS at LASUSTECH. The IACSLS successfully generated an average of 580 Wh in four hours of peak sunlight per day from a 145 W solar-PV panel, which is enough to power a 30 W LED bulb throughout the night. The system is 100% renewable and shows a surplus of 6.71 kWh per year, indicating it produces more energy than it needs. The total initial capital cost is estimated to be \$65.54, with a projected life span of 10 to 25 years. The deployed system consistently delivered over eight hours of lighting at night during load shedding offering a sustainable, cost-effective solution for improving night-time security activities on university campus.

© 2025 Faculty of Engineering, University of Maiduguri, Nigeria. All rights reserved.

1.0 Introduction

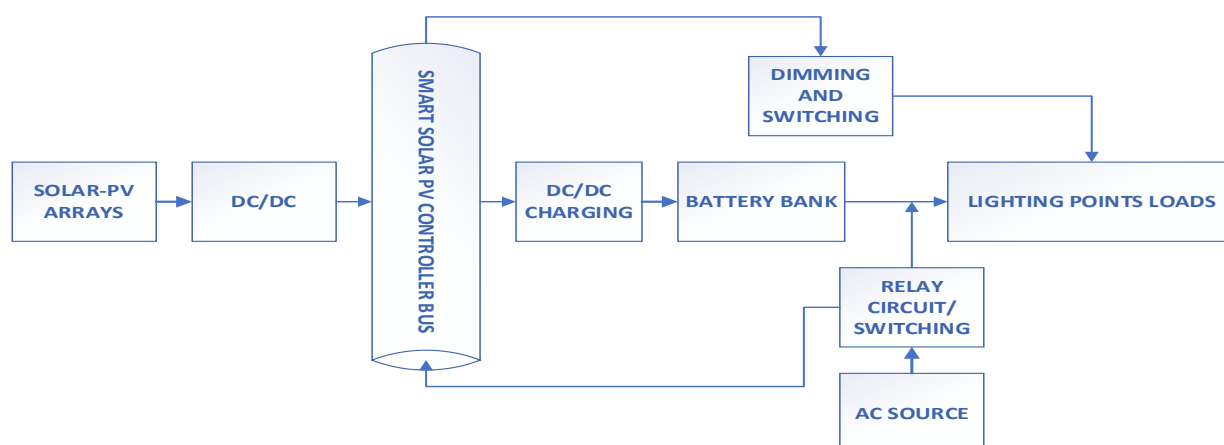
A consistent and reliable power supply is fundamental to ensuring a high quality of service delivery in university campuses worldwide which could significantly enhance teaching, research, and security services (Addeh, 2020). Unfortunately, many Nigerian universities are faced with these challenges due to unreliable power supply, thereby negatively impacting security activities, particularly at night hour. Using the Lagos State University of Science and Technology (LASUSTECH) as a case study, the observed load shedding events consistently plunge the campus into darkness during nighttime hours, severely frustrating adequate security service delivery from stationed personnel. Thus, to provide uninterrupted power supply during these outages, many institutions, including LASUSTECH, have resorted to diesel generators (DG) as a backup power source. However, the choice of DGs is difficult to justify due to their unsustainably high operational cost as well as their significant environmental and noise pollution problems (Sawle et al., 2016 and Olabode et al., 2021). While hybrid renewable energy supply systems (HRESS) have emerged as a promising solution to this problem, their high

initial procurement cost has historically limited their widespread application (Celik, 2003), (Kebede and Getachew, 2018), and (Ramunenyiwa *et al.*, 2020). Furthermore, recent advancements have seen the deployment of Solar-PV based standalone energy supply systems to illuminate university campuses and public street roads nationwide (Okandeji *et al.*, 2020). Despite this progress, this technology has proved to be limited in its capacity to cover all indoor dark spots within universities, such as offices, walkways, and lecture theatres, during nighttime load-shedding events. In view of these persistent challenges, this study proposes an improved smart energy-efficient lighting system: the alternating circuit (AC)-tied Solar-PV-based controlled lighting system (IACSLS). This novel renewable energy lighting system is designed to effectively eliminate all dark spots on university campuses at night, specifically when load-shedding is applied to the university's electricity feeder. By providing consistent illumination, the IACSLS significantly enhances security service delivery, improves campus nightlife activities to meet global standards, and consequently boosts the performance of both students and faculty members. This study's novelty lies in proposing an improved smart energy-efficient lighting system (IACSLS) that uniquely combines standalone Hybrid Renewable Energy Supply System (HRESS) technology with an intelligent AC source control circuit, designed to operate exclusively at night during load-shedding events, thereby eliminating dark spots across university campuses and enhancing security and nightlife activities.

## 2. Materials and Method

### 2.1 Research Materials

This section discusses the materials and method utilized for the development of the proposed IACSLS circuit components design. The IACSLS comprises of Solar-photovoltaic panels, direct current (DC) source/direct current converter (DC-converter), control circuit with dimming and switching (ON/OFF) sensor, battery bank, AC source and the loads (lighting points). Fig.1 presents the block diagram of the proposed IACSLS device.



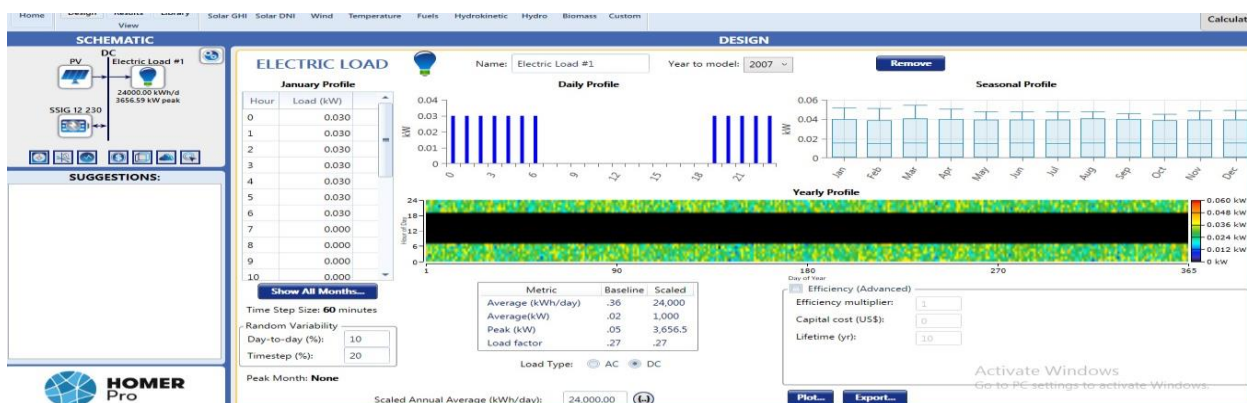
**Figure 1:** The schematic diagram of the proposed IACSLS.

### 2.2 Research Methodology

In this study, the engineering science principle backing the development of IACSLS is the optimization of electrical power conversion and system efficiency through enhanced thermal management and intelligent power electronics for seamless integration with AC loads. This involves electronic circuit design, signal processing, and control systems to enable the system to respond intelligently to external power sources when required at night only. In trying to maximize energy efficiency, the system's ability to deactivate when an AC signal is detected, minimizing energy waste, justified this task. The proposed IACSLS's model was simulated using HOMER-Pro software trial version. This allows evaluation of the system's performance under various conditions, optimizing the system design size, and predicting its long-term behavior. The device circuit construction was carried out at the electronic laboratory LASUSTECH and the implementation of the proposed IACSLS was carried out at the Electrical and Electronic Engineering Department of LASUSTECH, Ikorodu campus. The detailed discussion of each modelling and design stage presented in Figure 1 is presented.

## 2.3 Modelling of Daily IACSLS's Load Profile and Power Demand Assessment

The graphical users interface software HOMER Pro trial version, a microgrid software for designing optimized hybrid power supply system was used for this study. Figure 2 shows the HOMER-Pro modelling platform.



**Figure 2:** Daily energy consumption profile of the IACSLS. (Lilienthal & Gilman, 2004).

The per-hour load demand of the lighting bulbs is 30 W. It was determined that from 7:00 PM to 6:00 AM, the expected load demand should be in constant mode throughout the time of IACSLS's operation. Therefore, the electrical load of 30 W was used as based load. The proposed IACSLS is expected to function only at night when power utility companies apply load shedding to the university feeder. Therefore, it is good to note that the IACSLS switching operation between 7:00 PM to 6:00 AM is dynamics and not static. So, if IACSLS bulb is rated 30 Watts, and the power utility's load shedding lasted for only "X" hour(s) at night, the load requirement of the proposed IACSLS would be  $30 * X d^{-1} (Whrd^{-1})$  between 7:00 PM and 6:00 AM.

## 2.4 Daily Photovoltaic Energy Data Assessment

Solar energy is one of the inexhaustible renewable energy sources that are used to power Solar- Photovoltaic systems indefinitely. Good enough, Nigeria has an average daily sunlight hour of  $6.25 \text{ hd}^{-1}$ , with  $3.5 \text{ kWhm}^{-2}\text{d}^{-1}$  in coastal areas and  $9.0 \text{ kWhm}^{-2}\text{d}^{-1}$  in the far northern border of Nigeria as reported in (Omogoye *et al.*, 2015), (Omogoye *et al.*, 2016), and (Okandeji *et al.*, 2020) (Alayande *et al.*, 2025) respectively. Table I presents the daily average Solar incident experience in Electrical and Electronic Engineering Department of LASUSTECH Ikorodu, Lagos State Nigeria depicting that the chosen site has abundant inexhaustible Solar energy resources, good enough to implement the proposed IACSLS. The monthly average Solar radiation data is obtained from national aeronautics and space administration (NASA, 2015). An annual average Solar radiation for Electrical and Electronic Engineering Department is  $4.74 \text{ kW/m}^2\text{/day}$ , see Table I. Month of November has a maximum Solar energy resource of  $5.292 \text{ kW/m}^2\text{/day}$ . Fig. 3 shows the Solar radiation graph of the selected study location.

**Table I:** Daily average Solar incident on a horizontal surface (Lilienthal & Gilman, 2004)

Month	Clearness index	Month average radiation (kwh/m <sup>2</sup> /day)
January	0.528	4.917
February	0.519	5.128
March	0.506	5.236
April	0.486	5.082
May	0.475	4.842
June	0.444	4.433
July	0.384	3.855
August	0.382	3.922
September	0.419	4.323
October	0.503	5.016
November	0.563	5.292
December	0.535	4.864



**Figure 3:** Average monthly radiation curve with clearness index. (Lilienthal & Gilman, 2004).

## 2.5 Modelling of IACSLS Components

This section presents the proposed IACSLS's circuit components design as follows:

### 2.5.1 Modelling of IACSLS's load profile

Table 2 shows the proposed IACSLS's load profile design calculations. The proposed IACSLS lighting load of 30 W is used while battery efficiency of 0.96 percent is considered. The device was designed to function for at least eight hours of light out. In Table 3, the Solar-PV panel selection criteria was demonstrated. Table 4 presents the Solar-PV system load profile design selection calculation. In this work, the proposed IACSLS must supply the night load using the stored energy in the battery. Therefore, to supply needed energy to the load at night only, that amount of energy must be pre-loaded into the battery by the Installed Solar-PV array. The design calculation for this illustration is presented in Table 5. The MPPT charge controller designed in Table 6 is a type of buck boost converter. It is designed to optimize the power output from the Solar-PV panels by adjusting the voltage and current to find the maximum power point (MPP) of the Solar-PV panel's current operating conditions. In a buck-boost converter, the voltage can be either stepped up or stepped down, allowing the system to efficiently manage situations where the Solar-PV's panel voltage is higher or lower than the battery voltage. This versatility is why the MPPT controllers are used in this IACSLS's design, to maximize energy conversion and increase the overall efficiency of the system. The modelling of DC-DC converter is presented in Table 6. The proposed IACSLS circuitry design was done using a free trial version of HOMER-Pro software (Lilienthal & Gilman, 2004) trial version, on a personal computer (PC) of Intel core i-3. Electrical and Electronics Engineering Department of LASUSTECH walkways T-junction was used as a pilot space to mount the proposed IACSLS. These sets of equations are used in the design of the proposed IACSLS. To avoid repetition of the basic design equations, some of the equations used for the system design can be found in (Omogoye *et al.*, 2015), (Okandeji *et al.*, 2020), (Nigel and Longe, 2021).

**Table 2:** Solar PV system load profile design selection (Lilienthal & Gilman, 2004)

System components	Ratings
Lighting point load	30 W
Efficiency of the battery ( $E_b$ )	0.96
Watt hours of the load per day (night)	$30 \times 8 = 240 \text{ Wh}$
$Wh_{Load} = Wh_{night} \div E_b$	$240 \text{ Wh} \div 0.96 = 256.25 \text{ Wh}$

**Table 3:** Solar panel modelling (Lilienthal & Gilman, 2004)

Panel type	Flat
Rated capacity	145W
Temperature coefficient	-0.460
Operating temperature	45.00
Efficiency	14.40

**Table 4:** Solar PV system load profile design selection (Lilienthal & Gilman, 2004)

Components nominal ratings	Rated Values
Nominal battery voltage, $V_{bat.nominal}$	12.8 V
Peak load current, $I_{load\ peak\ current}$	$30\ W \div 12\ V = 2.5\ A$
Battery capacity/power 12 V, 22 Ah	$= 12 \times 22 = 264\ Wh$

**Table 5:** Solar PV array sizing design modelling (Lilienthal & Gilman, 2004)

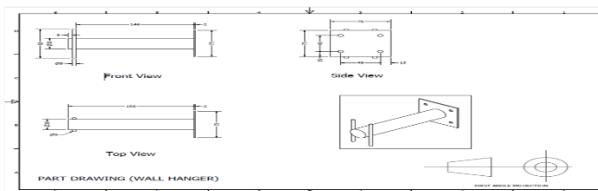
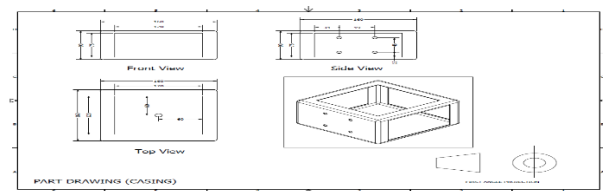
Design	Parameters
Days of autonomy	$na = 2$
Days of recharge	$nr = 2$
Watts-hour of PV	687.5 Wh
The Solar-PV array peak wattage considering the annual average (kWh/m <sup>2</sup> /day) = 4.74	$Pm = \frac{687.5\ wh}{4.74} = 145.04\ W$
The peak load of 145 W was considered.	Therefore, the selected Solar-PV panel is 145 W
The battery voltage	= 12 V
Therefore, Current (I) = power(P) ÷ voltage(V)	= $145 \div 12 = 12.08\ A$ . 12.08 A current is produced at output power of 145 W.
Charging time (in hours) = $\frac{Battery\ capacity\ (Ah)}{Charging\ current\ (A)}$	and, Charging current (I) = $\frac{Power(P)}{voltage(V)}$
Battery capacity	22 Ah
Solar panel power	145 W
Battery voltage	12 V
Charging current	$= \frac{145\ W}{12\ V} = 12.08\ A$
Charging time	$= \frac{18\ Ah}{12.08} = 1.49\ hrs$

**Table 6:** Calculation of DC-DC converter Maximum Power Point Tracking (MPPT) (Lilienthal & Gilman, 2004)

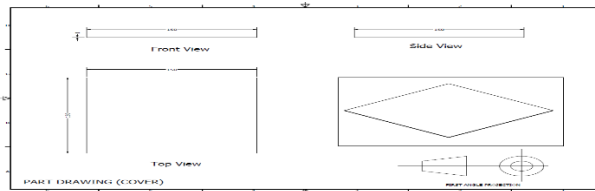
Components	Ratings
Solar panel power	145 W
Battery voltage	12 V
Battery capacity	22 Ah
Solar panel output current is calculated using power formula. Power = Current × Voltage	
Current	$= \frac{145\ W}{12\ V} = 12.08\ A$
It's common to have a buffer, so a charge controller that can handle at least 12 V, 15 A of current is chosen.	

## 2.6 IACSLS Casing Design

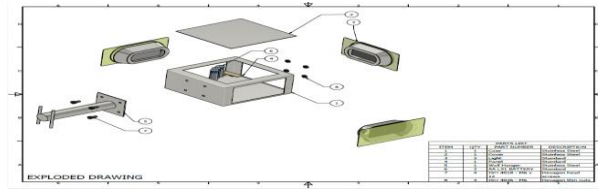
The IACSLS casing design involves the material selection, marking out and fabrication. The proposed IACSLS's component parts drawing for the wall hanger and casing were carried out at LASUSTECH Mechanical Engineering workshop. The indoor and outdoor casings final designs are presented in Figs., 4-12.


**Figure 4:** Wall Hanger component parts

**Figure 5:** Casing component parts

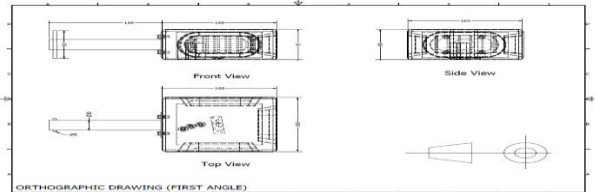




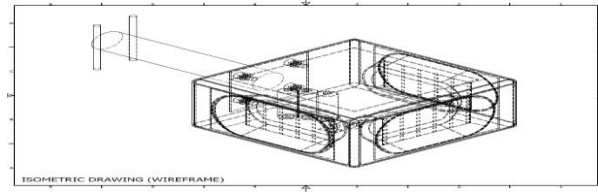
**Figure 6:** Casing cover parts



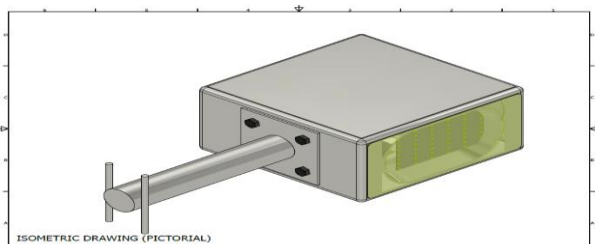
**Figure 7:** Exploded view of IACSLS



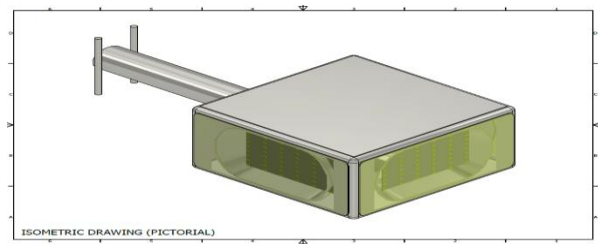
**Figure 8:** Orthographic projection



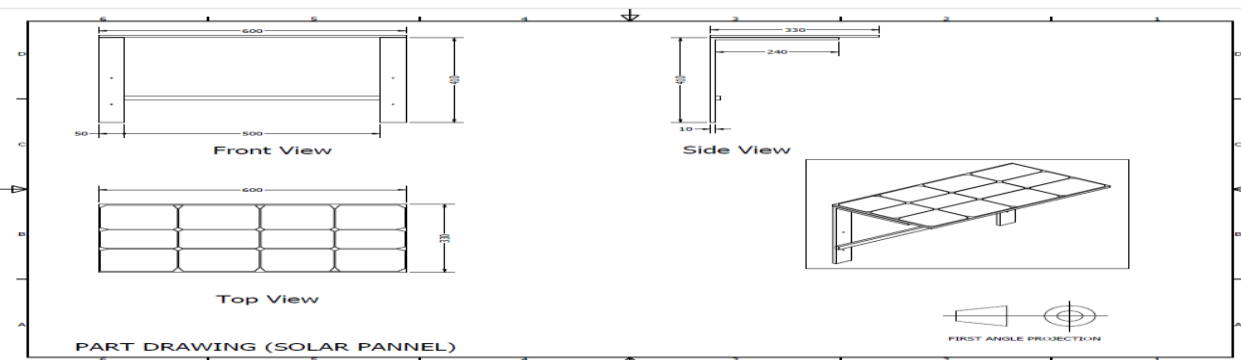
**Figure 9:** Wireframe of Isometric view



**Figure 10:** Pictorial back view Isometric drawing



**Figure 11:** Pictorial front view Isometric drawing



**Figure 12:** Pictorial view of the outdoor solar panel design

### 3. Results and Discussion

The simulation results obtained from HOMER-Pro software revealed that the 145 W Solar-PV panel consistently generated an average of 580 Wh per day. This output is sufficient to power the 30 W Light Emitting Diode (LED) bulbs during nighttime hours, especially with the seamless integration of a light control sensor. The intelligent smart control system of the IACSLS is crucial for ensuring optimal utilization of stored energy and significantly reducing overall energy wastage. This mechanism demonstrated accurate responsiveness to sunset, guaranteeing efficient energy consumption and effective illumination only when required. In the same vein, the IACSLS components comprise a 145 W Solar-PV panel, a 30 W LED, and a 12 V, 22 Ah battery. Table 7 presents the IACSLS's cost estimation. The initial capital cost for setting up this system is estimated at \$65.54, with an additional operational cost of approximately \$20.17 over the device's projected lifespan of 10 to 25 years.

This comprehensive cost analysis demonstrates the solar lighting system's strong financial viability and sustainability. The initial investment of \$65.54 covered essential components, including the 145 W Solar-PV panel, vital for harnessing renewable solar energy; the 30 W LED, responsible for efficient and targeted illumination; and the 12 V, 22 Ah battery, which ensures consistent power availability during nighttime operations. Furthermore, installation and wiring expenses of \$20 facilitated the seamless integration of the system. An estimated maintenance cost of \$258.55 over the 10-to-25-year lifespan underscores the system's

durability and minimal upkeep requirements. Strategic reliance on solar energy considerably reduces ongoing operational costs, as the system functions independently of external power sources. The system's salvage analysis indicates that components may depreciate over time, but their remaining value is still less than their original cost, contributing to the overall cost-effectiveness. The reported low operating cost highlights the system's affordability, long-term savings due to minimal operational expenditures, and its positive environmental impact through reduced dependence on non-renewable resources offers substantial benefits to environmental well-being. Additionally, the precise illumination control offered by the IACSLS significantly mitigates energy wastage. This approach aligns perfectly with Sustainable Development Goal 7 (SDG 7), Affordable and Clean Energy, as highlighted by (Ross, 2024), and supports long-term energy security. Similarly, regarding the IACSLS electricity production, in this design, the Kyocera KD 145 SX UFU Solar-PV panel was specifically chosen because of its robust electricity generation capabilities, producing approximately 51.4 kWh per year when operating at full capacity. In terms of electricity consumption, the AC primary load requires no energy, while the DC primary load consumes about 43.8 kWh per year at maximum usage. The deferrable load contributes zero consumption, resulting in a load of 0 kWh per year. The system exhibits a surplus of roughly 6.71 kWh per year, which constitutes 13.0 % of the total electricity generated. Regarding unmet electric load, there is a minimal value of 0.0221 kWh per year, representing only 0.0504 % of the total electricity generated. The capacity shortage is negligible, amounting to 0.0322 kWh per year, or 0.0735 % of the total generated electricity. The proposed IACSLS operates at a 100 % renewable fraction, indicating its exclusive reliance on solar energy for electricity generation. Remarkably, the maximum renewable penetration reaches an astonishing 1,694 %, showcasing the system's capacity to generate significantly more renewable energy than required. The power generated is available throughout the year, demonstrating that the proposed and constructed IACSLS is a reliable energy supply solution. In the same vein, the IACSLS efficiency and cost-effectiveness assessment were also quantified as key areas of focus. This pivotal avenue for optimization involves exploring the feasibility of integrating higher-capacity batteries. By incorporating batteries with greater energy storage capabilities, the system can accumulate surplus energy during peak sunlight hours, ensuring uninterrupted operation even during extended periods of low solar input. This optimization not only enhances energy resilience but also maximizes cost savings by harnessing excess energy that might otherwise go untapped. Furthermore, investigating the integration of energy-efficient or dimmable LEDs presents a promising avenue for reducing energy consumption without compromising illumination quality. These dual approaches of energy conservation and maintaining adequate lighting levels align perfectly with the project's overall efficiency goals.

**Table 7:** IACSLS's cost (Lilienthal & Gilman, 2004)

System components cost	Rate	IACSLS's Expected life span (Years)
Initial capital cost	\$65.54	10-25
Operational cost	\$20.17	
Installation and wiring expenses	\$20.00	
Maintenance cost	\$258.55	

However, the design was without considering some constraints for system design optimization. While the integration of higher-capacity batteries is promising, it necessitates careful consideration of budgetary implications and available physical space in the design casing for installation. It is vital to strike a balance between enhanced performance and the associated costs. The incorporation of energy-efficient or dimmable LEDs also warrants careful evaluation. While these LEDs offer potential energy savings, their initial upfront costs and compatibility with the system's design should be thoroughly considered. In addition, system orientation, particularly the positioning of the Solar-PV panel, is crucial for optimal energy capture. This is because geographical and architectural limitations may constrain the extent to which orientation can be optimized. The overall budget and the available technology landscape are overarching constraints to keep in mind. While optimizing the system can offer long-term savings, it's essential to ensure that these optimizations align with the project's financial scope and available resources. By carefully weighing economic benefits against system limitations, a harmonious equilibrium can be struck, resulting in a solar lighting system that excels in both efficiency and cost-effectiveness.

The last aspect of this work to be described is the assemblage and mounting of the proposed IACSLS hardware components and its functionality. The proposed IACSLS hardware components made were meticulously assembled at LASUSTECH's Electronic and Communication Laboratory. The final production of the device is visually represented in Plate 1. This device has been successfully mounted at the Electrical and Electronic Engineering Department, LASUSTECH Ikorodu, Lagos, Nigeria, as also depicted in Plate 1. The system's ability to provide over eight hours of continuous lighting effectively justifies its application for enhancing security service delivery at night on campus.



**Plate 1:** Finished and mounted IACSLS device.

#### 4. Conclusion

In the pursuit of a sustainable and energy-efficient solution, this research developed a smart energy-efficient lighting system using AC-tied, Solar-PV with a light sensitivity control device to enhance LASUSTECH's security apparatus at night. The utilization of the trial version of HOMER-Pro simulation software has been instrumental in evaluating and optimizing the system's size and performance. Through meticulous simulation, the Solar lighting system's components, including the Kyocera KD 145 SX UFU Solar-PV panel, were assessed for their electricity generation, consumption patterns, and operational efficiency. These simulation-driven insights have been pivotal in shaping the design and ensuring that the system meets its performance objectives. A unique aspect of this smart energy-efficient lighting system using AC-tied, Solar-PV with light sensitivity control device is its intelligent response to AC signals and optimal energy delivery using a sensor. The system's capability to deactivate upon detecting an AC signal, optimizing the energy usage with the dimming sensor, with its illumination that covers 180° surface area further underscores its adaptability and the integration of advanced control mechanisms. This innovation not only ensures energy savings but also demonstrates a versatile solution that can harmoniously coexist with other energy sources. The case study at LASUSTECH serves as a testament to the real-world applicability of such technology at a reduced cost. Since the IACSLS's components are locally sourced. The successful design and implementation of the IACSLS device within the university's premises showcase the potential for renewable energy adoption within educational institutions, contributing to a culture of environmental consciousness and sustainable practices under SDG 7 of Times Higher Education (THE).

Conclusively, the research's journey from conceptualization, to design, simulation, and construction highlighted the synergy between technology, sustainability, and real-world impact. The integration of the HOMER-Pro simulation software into the project's fabric has substantiated the viability of the IACSLS device, affirming its role as an energy-efficient, eco-friendly, and intelligent solution from core engineering principle of photovoltaic effect to enhance security service delivery in Nigerian Universities at night. In the future we plan to scale up its production which will lead to the total cost reduction of this proposed device.

#### Acknowledgement

This work was supported by the LASUSTECH Research Grants (LRG) 2023, from Lagos State University of Science and Technology (LASUSTECH), Ikorodu, Lagos State, Nigeria.

#### References

Okandeji, AA., Jagun ZO., Olajide MB., Kabir MT. and Onaifo F. 2020. Design and implementation of Solar streetlight for scarcely electrified areas. *Arid Zone Journal of Engineering, Technology & Environment*, (Nigeria), 16(3): 543–560.

Addeh, E. (2020, July 13). Powering Nigeria's Universities - THISDAYLIVE. Thisdaylive.

Celik, AN. 2003. Optimisation and techno-economic analysis of autonomous photovoltaic-wind hybrid energy systems in comparison to single photovoltaic and wind systems. *Fuel and Energy Abstracts*, 44(3): 162-168. [https://doi.org/10.1016/S0140-6701\(03\)81833-7](https://doi.org/10.1016/S0140-6701(03)81833-7)



Alayande, AS., Emmies, AE., Okakwu, IK., Gbenga, OK. and Okeolu, OS. 2025. HOMER Pro-Based approach for designing and optimizing a grid-tied hybrid renewable energy system for a rural community. *Arid Zone Journal of Engineering, Technology & Environment*, 21(1): 72–86.

Kebede, MH. and Beyene, and GB. 2018. Feasibility Study of PV-Wind-Fuel Cell Hybrid Power System for Electrification of a Rural Village in Ethiopia. *Journal of Electrical and Computer Engineering*, 2018: Article ID 4015354:1–9. <https://doi.org/10.1155/2018/4015354>

Lilienthal, P. and Gilman, P. 2004. HOMER Modelling Software. National Renewable Energy Laboratory, 1–2.

NASA. 2015. Cloud Cover and Solar Radiation 82. In *Cloud Cover and Solar Radiation*, 990(1):3–5. [http://scool.larc.nasa.gov/lesson\\_plans/CloudCoverSolarRadiation.pdf](http://scool.larc.nasa.gov/lesson_plans/CloudCoverSolarRadiation.pdf)

Nigel, FT. and Longe, OM. 2021. Smart energy efficient lighting system for smart buildings. *IEEE PES/IAS PowerAfrica*: 1–6. <https://doi.org/10.1109/PowerAfrica52236.2021.9543273>

Omogoye, OS., Ogundare, AB. and Akanji, IO. 2015. Development of a cost-effective solar/diesel independent power plant for a remote station. *Journal of Energy*, 2015(Article ID 828745): 1–10. <https://doi.org/10.1155/2015/828745>

Olabode, OE., Ajewole, TO., Okakwu, IK., Alayande, AS. and Akinyele, DO. 2021. Hybrid power systems for off-grid locations: A comprehensive review of design technologies, applications and future trends. *Scientific African*, 13: e00884. <https://doi.org/10.1016/j.sciaf.2021.e00884>

Omogoye, OS., Ogundare, AB., Oyetola, JB., Keshinro, KK., and Adenle, JG. 2016. Feasibility Studies of a Proposed Hybrid Power Generation System for a Computer Center In a Remote Station. *International Journal of Technical Research and Applications*, 4(4): 113–119.

Ramunenyiwa, T., Awodele, K. and Omogoye, OS. 2020. Development of a cost-effective solar-wind-fuel cell independent power plant for a remote base transceiver station. 2020 International SAUPEC/RobMech/PRASA Conference, SAUPEC/RobMech/PRASA 2020: 1–6.

Ross, D. 2024. Impact Rankings Methodology 2024, Times Higher Education.

Sawle, Y., Gupta, SC. and Bohre, AK. 2016. PV-wind hybrid system: A review with case study. *Cogent Engineering*, 3(1): 1–31. <https://doi.org/10.1080/23311916.2016.1189305>