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DESIGN AND CONSTRUCTION OF A LOW-COST, ECO-FRIENDLY LIGHTING SOLUTION FOR DEVELOPING COMMUNITIES

BY

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PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF PHYSICS IN PARTIAL FULFILLMENT OF THE REQUIREMENT OF THE AWARD OF THE DEGREE OF BACHELORS OF SCIENCE EDUCATION OF BUSITEMA UNIVERSITY.

MAY, 2026

Declaration

I, Watulo Jackson, hereby declare that this research is my origin work and has not been submitted to any institution for the award of an academic qualification. Any work or idea that are not my own have been duly acknowledged and properly referenced.

Signature ....

Date 08/05/2026

Approval

This is to certify that the research topic titled **"Design and construction of a Low-Cost, Eco-Friendly Lighting Solution for Developing Communities"** has been carried out under my supervision and is hereby to be approved for submission in the partial fulfillment of the requirement for the award of the degree of Bachelors of Science with Education of Busitema University, Nagongera Campus.

Name ofsupervisor: **DR. Akoba Rashidah**

Signature

Date… 05th / 08/2026

Dedication

I dedicate this work to parents, my father Bukuwa Kalisiti and mother Nasila Mary for all the sacrifices they made to bring me up, nurture me and their continuous support. My humble pray for them is that God to bless them and protect them in everything that they do, grand them wisdom and long life so that they will enjoy from their hard work. May He increase your faith, love and hope in him in your life-time.

Acknowledgement

I want to extend my heartfelt sincere appreciation to Almighty God for the life, good health, strength and courage that he has granted to me throughout my time here at Busitema University. Many thanks go to my supervisor Dr. Akoba Rashidah for the guidance and continuous support and encouragement towards the completion of this project. More thanks goes to the research coordinator, Dr.Senyuzi Cliffe Richard for the services towards my project for his good coordination and guidance and all the activities he offered to my research and all the lectures from the faculty of science and education, more so the department of Physics at Busitema University for the good services given through conducting lectures and assessment. I am grateful to all my course mates, Wesonga Emmanuel, kibalatsi Fred, Watsena Silva, Kajubi Paul, Wenyaa Esther, Butuma Elisaphani, Namisano Herbert, Wonasola John and all the class of 2026 for their camaraderie, assistance and encouragement throughout the time we have been at Busitema University.

Abstract

This study focused on the design and construction of a low-cost, eco-friendly lighting solution for developing communities with limited access to reliable electricity. Many households in rural and low-income areas continue to depend on kerosene lamps, candles, and dry-cell batteries, which are expensive, unsafe, and harmful to both human health and the environment. The main objective of the study was to develop an affordable and sustainable lighting system using locally available materials and renewable energy principles. The system was designed using a transparent plastic water bottle filled with clean water and a small amount of bleach, combined with a solar panel, rechargeable battery, and LED lighting system. Experimental methods were used in the construction, testing, and evaluation of the system. Parameters such as battery charging performance, LED discharge performance, illumination coverage, and overall system effectiveness were investigated. The water-filled bottle improved light distribution by spreading light more uniformly within the room and reducing glare. Compared to traditional lighting sources such as kerosene lamps and candles, the system was found to be more cost-effective, environmentally friendly, and suitable for household use. The study concluded that the solar-powered water bottle lighting system is a practical and sustainable lighting solution for off-grid and low-income communities. It reduces dependence on fossil-fuel-based lighting, lowers household energy costs, and promotes the use of clean energy technologies.

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List of Acronym and Abbreviations

LED …………Light Emitting Diode

WHO………. world Health Organization

IEA…………. International Energy Agency

SDG ………..Sustainable developmental goal

NGO ………..Non-Government organization

IPPC………. Intergovernmental Panel on Climate Change

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This chapter contains the background, problem statement, general objectives, specific objects, significance and scope of the study.

1.1 Background

Access to adequate lighting is a fundamental requirement for education, economic productivity, security, and improved quality of life. Lighting enables individuals to extend productive activities beyond daylight hours and contributes significantly to social and economic development. Despite advances in lighting technologies globally, millions of people in developing communities continue to experience limited access to reliable and affordable lighting solutions. According to the International Energy Agency (IEA, 2023), a significant proportion of rural households in developing countries still lack access to electricity, forcing them to rely on traditional lighting sources such as kerosene lamps, candles, and open-flame lanterns. The use of traditional lighting systems presents numerous challenges. Kerosene lamps produce harmful emissions that contribute to indoor air pollution and respiratory diseases. Furthermore, these lighting methods are inefficient, expensive in the long term, and environmentally unsustainable due to their carbon emissions and dependence on fossil fuels (World Bank, 2022). As concerns about environmental conservation and sustainable development continue to increase, there is a growing need for low-cost and eco-friendly lighting alternatives that can meet the needs of underserved populations. Recent technological advancements have led to the development of renewable energy-based lighting solutions such as solar-powered lamps, solar bottle bulbs, and light-emitting diode (LED) systems. These technologies offer environmentally friendly alternatives while reducing operational costs. However, many commercially available systems remain unaffordable for low-income households due to high initial installation costs and limited accessibility in rural markets (United Nations Development Programme [UNDP], 2023). Consequently, there is a need to design and construct simple, low-cost, and eco-friendly lighting systems using readily available materials. Such systems can provide affordable lighting while promoting environmental sustainability and improving living standards in developing communities. Globally, access to electricity remains uneven despite significant investments in energy infrastructure. The United Nations reports that approximately 675 million people worldwide still lack access to electricity, with the majority residing in Sub-Saharan Africa and parts of Asia (United Nations, 2023). Lack of electricity directly affects access to quality lighting, limiting educational opportunities, economic activities, and healthcare services. Traditional lighting technologies have been widely used in off-grid communities. Kerosene lamps remain common because they are relatively inexpensive to acquire. However, they consume fuel continuously, making them costly over time. Research by Mills (2016) indicates that households relying on kerosene spend a substantial proportion of their income on fuel purchases. In addition, kerosene combustion releases carbon dioxide, black carbon, and other pollutants that negatively affect both human health and the environment. The growing awareness of climate change has intensified efforts to promote renewable and sustainable energy solutions. Sustainable Development Goal 7 emphasizes ensuring access to affordable, reliable, sustainable, and modern energy for all by 2030 (United Nations, 2023). Low-cost lighting innovations are therefore essential for achieving global energy access targets. Developing communities face numerous challenges related to energy access and lighting. Rural populations often live far from national electricity grids, making grid extension economically difficult and technically challenging. Even where electricity infrastructure exists, frequent power outages and high electricity tariffs limit accessibility. As a result, households often depend on alternative lighting methods such as candles, kerosene lamps, and battery-powered torches. While these methods provide temporary lighting, they are associated with several disadvantages. Candles present fire hazards, kerosene lamps produce smoke and toxic emissions, and disposable batteries contribute to environmental pollution through improper disposal (World Health Organization [WHO], 2022). Educational outcomes are particularly affected by inadequate lighting. Students in poorly lit homes experience difficulties studying during evening hours, leading to reduced academic performance. Similarly, small businesses are unable to operate efficiently after sunset, reducing household income opportunities (UNDP, 2023). The development of affordable lighting technologies therefore represents an important strategy for enhancing social and economic development in rural communities. Eco-friendly lighting refers to lighting systems that minimize environmental impact while providing effective illumination. Such systems are designed to reduce energy consumption, decrease greenhouse gas emissions, and utilize sustainable materials. Among the most widely adopted eco-friendly lighting technologies are LEDs. LED lamps consume significantly less electricity compared to incandescent and fluorescent bulbs while providing higher luminous efficiency and longer lifespan (U.S. Department of Energy, 2022). Their low power requirements make them particularly suitable for solar-powered applications. Solar energy has emerged as one of the most promising renewable energy sources for lighting applications. Solar-powered lighting systems convert sunlight into electrical energy through photovoltaic panels, which is then stored in batteries for later use. These systems provide clean and renewable lighting without recurring fuel costs. Another innovative solution is the solar bottle bulb. Originally developed in communities lacking electricity, solar bottle bulbs use transparent plastic bottles filled with water and bleach to refract sunlight into indoor spaces. This technology provides daytime illumination at virtually no operating cost while utilizing recycled materials (Moser, 2015). These eco-friendly technologies demonstrate the potential of sustainable lighting solutions in addressing energy poverty. Affordability is a critical factor influencing the adoption of lighting technologies in developing communities. Many households operate on limited incomes and cannot afford expensive lighting systems despite their long-term benefits. Low-cost lighting systems offer several advantages. First, they reduce financial barriers to adoption. Second, they encourage local participation in construction and maintenance. Third, they increase accessibility by utilizing locally available materials. The concept of appropriate technology emphasizes designing solutions that are affordable, simple, and suited to local conditions (Schumacher, 1973). In the context of lighting, appropriate technologies prioritize simplicity, low maintenance requirements, and local resource utilization. Research has shown that community-based lighting solutions are more likely to achieve long-term sustainability when they can be maintained using locally available skills and materials (Practical Action, 2022). Therefore, designing a low-cost lighting system using readily available materials aligns with principles of sustainable development and community empowerment. The design of an effective lighting system involves balancing performance, cost, durability, and environmental impact. For developing communities, simplicity is particularly important because complex systems may require specialized maintenance skills. Several factors must be considered during design. These include the source of energy, illumination level, material availability, ease of construction, and system lifespan. Renewable energy sources such as solar power provide significant advantages due to their availability and environmental friendliness. Materials selected for construction should be inexpensive, durable, and easily accessible. Recycled materials can further reduce costs while promoting environmental conservation. The system should also be designed for ease of assembly to facilitate community participation. A well-designed lighting system should provide adequate illumination for household activities while minimizing energy consumption. Such considerations form the foundation for developing sustainable lighting solutions suitable for resource-constrained environments. Construction represents the practical implementation of the design process. The use of locally available materials reduces costs and increases community ownership of the technology. Examples of materials commonly used in low-cost lighting projects include plastic bottles, LED bulbs, solar panels, rechargeable batteries, switches, wiring components, and recycled containers. These materials can often be sourced locally at relatively low prices. Community involvement during construction contributes to knowledge transfer and skill development. Households that understand the construction process are better equipped to maintain and repair the system independently. Furthermore, local construction minimizes dependence on imported products and promotes local innovation. This supports economic development while enhancing the sustainability of the technology. Efficiency is a key performance indicator for lighting systems. Lighting efficiency refers to the ability of a system to convert energy into useful light output. LED technology has significantly improved lighting efficiency compared to traditional lighting systems. According to the U.S. Department of Energy (2022), LEDs can achieve efficiencies exceeding 80%, making them among the most energy-efficient lighting technologies available. Evaluation of efficiency involves measuring factors such as illumination intensity, energy consumption, battery performance, and operating duration. Efficient systems provide adequate lighting while consuming minimal energy resources. Assessing efficiency is essential for determining whether the developed lighting system meets its intended objectives and performs effectively under real-world conditions. Affordability determines whether a lighting solution can realistically be adopted by target communities. Evaluation of affordability includes assessing initial costs, maintenance costs, and long-term operating expenses. Traditional lighting systems may appear inexpensive initially but often involve recurring fuel costs. In contrast, renewable energy-based lighting systems may require higher initial investment but provide substantial savings over time. Cost-benefit analysis is commonly used to evaluate affordability. This involves comparing installation and maintenance costs against expected benefits such as reduced energy expenditure and improved productivity. A truly affordable lighting solution should minimize both initial and long-term costs while maintaining acceptable performance standards. Sustainability refers to the ability of a system to meet present needs without compromising future generations' ability to meet their own needs (Brundtland Commission, 1987). Environmental sustainability is achieved by reducing energy consumption, minimizing waste generation, and utilizing renewable resources. Social sustainability involves improving quality of life and supporting community development. Economic sustainability requires that the system remains financially viable over time. The proposed lighting solution seeks to integrate all three dimensions of sustainability by utilizing eco-friendly materials, reducing operational costs, and improving access to reliable lighting. Evaluating sustainability therefore provides insight into the long-term viability and impact of the developed system. Despite the availability of various lighting technologies, many developing communities continue to face challenges related to affordability, accessibility, and sustainability. Existing commercial solutions are often beyond the financial reach of low-income households. There is therefore a need for innovative approaches that combine low cost, environmental friendliness, and ease of construction. Designing and constructing a simple lighting system using readily available materials provides an opportunity to address these challenges while promoting sustainable development. The study seeks to contribute practical knowledge on the development of affordable lighting technologies that can improve living conditions in underserved communities. By evaluating efficiency, affordability, and sustainability, the study will provide evidence regarding the feasibility of implementing such systems on a larger scale. Access to affordable and sustainable lighting remains a significant challenge in many developing communities. Traditional lighting methods are associated with environmental, economic, and health-related disadvantages, highlighting the need for alternative solutions. Eco-friendly lighting technologies such as LEDs and solar-powered systems offer promising opportunities for addressing energy poverty while promoting environmental conservation. The design and construction of a low-cost lighting system using readily available materials aligns with global sustainable development goals and has the potential to improve educational outcomes, economic productivity, and quality of life. Therefore, evaluating the efficiency, affordability, and sustainability of such a system is essential for determining its suitability for widespread adoption in developing communities.

1.2 Problem Statement

Access to safe, affordable, and environmentally friendly lighting remains a major challenge in many developing communities, particularly in rural and low-income areas. A significant number of households still depend on traditional lighting sources such as kerosene lamps, candles, and firewood-based lighting due to limited access to electricity and the high cost of modern energy solutions. However, these traditional lighting methods are inefficient and have serious negative impacts. Health: They produce indoor air pollution leading to respiratory infections, eye irritation and other illnesses, particularly children and women, Economic: They increase household expenditure over time, Environmental: They contribute to pollution through carbon emission. Although renewable and energy-efficient lighting technologies such as solar-powered systems and LED lighting exist, their adoption in low-income communities remains limited due to high initial costs, lack of technical knowledge, and limited availability of affordable products. This creates a gap between the need for clean lighting and the accessibility of practical, low-cost solutions. Therefore, there is a need to design and develop a low-cost, eco-friendly lighting solution that is affordable, safe, energy-efficient, and suitable for use in developing communities

1.3 Main objectives of the Study

The purpose of this study is to design and construct a low-cost, eco-friendly lighting system suitable for households in developing communities with limited or no access to reliable electricity. The study focuses on developing a sustainable lighting solution that is affordable, energy-efficient, and environmentally safe.

1.4 Specific objectives

This study was guided by the following objectives

- To design a simple lighting system using readily available and low-cost materials.
- To construct a simple system using readily available and low-cost materials
- To evaluate the efficiency, affordability, and sustainability of the proposed lighting system.

1.5 Significance of the study

This study on the design and construction of a low-cost eco-friendly lighting solution for developing communities is significant in addressing both local energy challenges and global sustainability priorities. Firstly, it contributes to SDG 7: Affordable and Clean Energy by promoting access to affordable, reliable, and modern lighting alternatives for communities that still depend on unsafe and expensive energy sources such as kerosene lamps and candles. This helps improve energy access and household living conditions (United Nations, 2015). Secondly, the study supports SDG 13: Climate Action by reducing reliance on fossil-fuel-based lighting systems, thereby lowering carbon emissions and indoor air pollution. This contributes to environmental protection and climate change mitigation efforts. Thirdly, it aligns with SDG 1: No Poverty by reducing household expenditure on lighting energy. The cost savings enable families to redirect limited financial resources to other essential needs such as food, education, and healthcare, improving their overall welfare. In addition, the study promotes SDG 3: Good Health and Well-being by minimizing exposure to harmful smoke produced by traditional lighting sources, which are associated with respiratory diseases and eye irritation.

CHAPTER TWO: LITERATURE REVIEW.

2.0 Introduction

This chapter reviews literature related to the design, construction, efficiency, affordability, and sustainability of low-cost eco-friendly lighting solutions for developing communities. The review is organized according to the study objectives. It examines existing lighting technologies, design approaches, construction methods, and evaluation criteria relevant to sustainable lighting systems. The chapter also identifies research gaps that justify the present study.

2.1 To Design a Simple Lighting System Using Readily Available and Low-Cost Materials

2.1.1 Concept of Low-Cost Eco-Friendly Lighting Systems

Low-cost eco-friendly lighting systems are lighting technologies designed to provide adequate illumination while minimizing environmental impact and financial costs. Such systems typically utilize renewable energy sources, energy-efficient lighting devices, and locally available materials to ensure affordability and sustainability (International Energy Agency [IEA], 2023). According to Schumacher (1973), appropriate technologies for developing communities should be simple, affordable, easy to maintain, and adaptable to local conditions. Lighting systems designed using these principles are more likely to achieve long-term acceptance and sustainability. Researchers have increasingly focused on developing lighting solutions that can operate independently of conventional electricity grids. These systems often incorporate solar energy, recycled materials, and low-energy-consuming LEDs to provide reliable lighting in off-grid areas (Bhattacharyya, 2019).

2.1.2 Design Principles of Sustainable Lighting Systems

The design of sustainable lighting systems involves optimizing illumination while minimizing energy consumption and environmental impact. According to DiLouie (2020), an effective lighting design should satisfy three major requirements: adequate brightness, energy efficiency, and economic viability. Sustainable lighting systems are generally characterized by: Low energy consumption, use of renewable energy sources, long operational lifespan, Minimal environmental impact and Affordability for target users. The integration of LED technology into lighting systems has significantly improved lighting efficiency. LEDs consume up to 80% less energy than traditional incandescent bulbs and can last up to 25 times longer (U.S. Department of Energy, 2022).

2.1.3 Solar-Based Lighting Designs

Solar-powered lighting systems have become increasingly popular due to their environmental and economic benefits. Solar energy is abundant, renewable, and freely available in many developing regions, particularly in Sub-Saharan Africa (World Bank, 2022). A typical solar lighting system consists of: A solar panel, Rechargeable battery, Charge controller, LED light source, Electrical wiring and switches. According to Chaurey and Kandpal (2010), solar lighting systems provide a viable solution for rural electrification because they eliminate recurring fuel costs while reducing carbon emissions. Studies conducted in Kenya, Uganda, and Tanzania have demonstrated that solar-powered lighting systems improve educational performance, household productivity, and economic activities by extending working hours after sunset (UNDP, 2023).

2.1.4 Use of Readily Available Materials in Lighting Design

The use of locally available materials significantly reduces production costs and increases accessibility. Practical Action (2022) emphasizes that technologies based on local materials are easier to maintain and repair than imported systems. Several researchers have investigated the use of recycled materials in lighting applications. Moser (2015) introduced the Solar Bottle Bulb project, which utilizes discarded plastic bottles filled with water and bleach to refract sunlight into buildings during daytime. This innovation demonstrated how waste materials can be transformed into useful lighting technologies. Similarly, recycled containers, plastic casings, scrap wiring, and locally sourced mounting structures have been successfully integrated into low-cost lighting systems across developing countries (UN-Habitat, 2021). Although numerous studies have explored solar and LED lighting technologies, many focus on commercially manufactured systems that remain expensive for low-income households. Limited studies have concentrated on designing integrated lighting systems using entirely low-cost and locally available materials suitable for developing communities. This study seeks to bridge this gap by designing a simple eco-friendly lighting system using readily available resources.

2.2 To Construct a Simple Lighting System Using Readily Available and Low-Cost Materials

2.2.1 Construction of Low-Cost Lighting Systems

Construction refers to the practical assembly and implementation of the designed lighting system. Successful construction requires selecting suitable materials, ensuring system reliability, and minimizing production costs. According to Fraenkel and Wallen (2018), practical implementation is essential for evaluating the feasibility of engineering designs. The construction phase provides an opportunity to identify technical challenges and optimize system performance. Researchers have demonstrated that low-cost lighting systems can be constructed using readily available components such as: Small photovoltaic panels, LED bulbs, Rechargeable batteries, Plastic housings like plastic water bottle, Electrical switches., Recycled containers. These materials are generally inexpensive and widely available in local markets (World Bank, 2022).

2.2.2 LED Technology in Lighting Construction

LEDs have become the preferred lighting source in sustainable lighting systems due to their high efficiency and durability. According to the U.S. Department of Energy (2022), LEDs convert a higher percentage of electrical energy into visible light compared to incandescent and fluorescent lamps. LEDs offer several advantages: Low power consumption, Long lifespan, Reduced heat generation, Compact size and High reliability. These characteristics make LEDs particularly suitable for low-cost lighting projects where energy conservation is a major objective.

2.2.3 Solar Energy Integration During Construction

The integration of solar energy components is a critical aspect of constructing eco-friendly lighting systems. Solar photovoltaic technology converts sunlight directly into electricity without producing greenhouse gas emissions (IEA, 2023). Research by Chaurey and Kandpal (2010) indicates that properly designed solar lighting systems can operate efficiently for several years with minimal maintenance requirements. The use of rechargeable batteries allows energy generated during the day to be stored and used during nighttime hours. For rural communities, solar-powered lighting systems reduce dependence on kerosene and grid electricity while improving energy security.

2.2.4 Community-Based Construction Approaches

Community participation has been identified as a key factor in the successful implementation of rural technologies. According to Practical Action (2022), involving community members during construction enhances local ownership and improves long-term sustainability. Participatory construction approaches offer several benefits: Knowledge transfer, Skill development, Reduced labor costs, Improved maintenance capability and Increased acceptance of the technology. These benefits contribute to the overall success of low-cost lighting projects.

2.2.5 Research Gap

Previous studies have concentrated primarily on evaluating existing lighting products rather than constructing systems from locally available materials. There is therefore a need for practical studies that demonstrate the complete construction process of low-cost eco-friendly lighting solutions suitable for developing communities. Efficiency is one of the most important indicators of lighting system performance. Lighting efficiency is commonly measured by the amount of useful light produced per unit of energy consumed (DiLouie, 2020). LED lighting systems have been widely recognized for their superior efficiency. According to the U.S. Department of Energy (2022), modern LEDs achieve luminous efficacies exceeding 100 lumens per watt, compared to approximately 15 lumens per watt for incandescent bulbs. Efficiency evaluation typically includes; Illumination intensity, Energy consumption, Battery performance, Operating duration and Light distribution. Studies conducted by Mills (2016) found that LED-based solar lighting systems provide significantly higher lighting efficiency than kerosene lamps while reducing energy costs.

2.3.2 Evaluation of Affordability

Affordability refers to the economic accessibility of a technology to intended users. In developing communities, affordability is often the most critical determinant of technology adoption (Bhattacharyya, 2019). Evaluation of affordability involves assessing: the initial construction costs, maintenance costs, replacement costs, operational costs and payback period. Research by the World Bank (2022) shows that households using solar lighting systems experience substantial long-term savings due to the elimination of fuel expenses associated with kerosene lamps. Cost-benefit analysis is frequently used to compare lighting alternatives and determine economic feasibility. Sustainability encompasses environmental, social, and economic dimensions. The

Brundtland Commission (1987) defines sustainability as meeting present needs without compromising future generations' ability to meet their own needs. Environmental sustainability involves reducing greenhouse gas emissions and minimizing resource depletion. Solar-powered lighting systems contribute to environmental sustainability by utilizing renewable energy and reducing fossil fuel consumption (United Nations, 2023). Social sustainability focuses on improving quality of life through enhanced access to lighting. Adequate lighting supports education, healthcare delivery, security, and economic activities (UNDP, 2023). Economic sustainability ensures that the system remains financially viable throughout its operational life. Low maintenance requirements and minimal operating costs contribute significantly to economic sustainability. Several studies have compared traditional lighting systems with renewable-energy-based alternatives. Mills (2016) found that solar LED systems reduce carbon emissions by over 90% compared to kerosene lamps while providing better illumination quality. Similarly, World Health Organization (2022) reports indicate that replacing fuel-based lighting with clean energy technologies significantly improves indoor air quality and reduces respiratory health risks. These findings demonstrate the potential of eco-friendly lighting systems to address multiple development challenges simultaneously. Although previous studies have separately evaluated efficiency, affordability, and sustainability, few studies have comprehensively assessed all three factors within a single low-cost lighting system developed from locally available materials. Therefore, this study seeks to evaluate the efficiency, affordability, and sustainability of the proposed lighting system in an integrated manner.

CHAPTER THREE: MATERIALS AND METHODS

3.0 Introduction

This chapter explains the procedures and methods used in the design, construction, and testing of the solar bottle lighting system. It covers the materials used, system design, experimental setup, and how data was collected and analyzed.

3.1 Materials Used

The materials used in this study were selected based on low cost, local availability, and ease of use. They include: Transparent plastic water bottle (1.5 liters) filled with clean water, Clean water mixed with a small amount of bleach (to prevent algae growth), Box cardboard for mounting the bottle, Sealant (epoxy or silicone) to prevent water leakage, Cutting tools (knife or metal cutter), Measuring tools (ruler, marker), Protective gloves and safety equipment, solar panel for charging the battery during day time, rechargeable battery for storing electrical energy, LED light for providing illumination light at night, connecting wires for electrical connection.

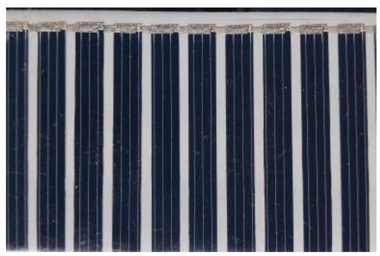

Figure3.1: Showing the solar panel

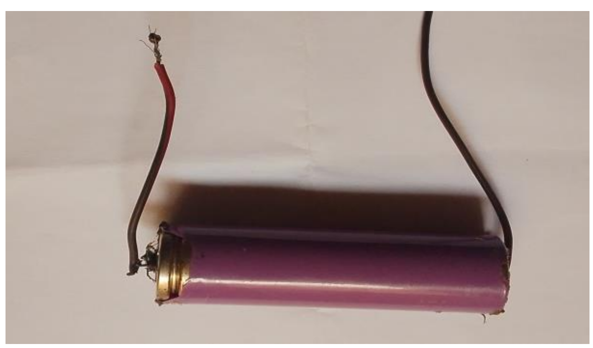

Figure 3.2 showing a rechargeable battery

3.2 Methods used in the construction process

The construction of the solar water bottle lighting system involved the following steps:A transparent plastic bottle was cleaned and filled with water mixed with a small amount of bleach, A hole matching the diameter of the bottle was cut into a box roofing sheet, The bottle was inserted halfway through the hole in the box sheet, Sealant was applied around the bottle to prevent leakage and secure it firmly, The setup was installed on a roof, ensuring the top part is exposed to sunlight while the lower part remains inside the room, The system is based on the principle of light refraction. When sunlight strikes the water-filled plastic bottle, the light is refracted and dispersed due to the difference in the refractive index between water, air and plastic bottle. This causes the light to disperse evenly throughout the room rather than remaining as a condensed beam.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents the results obtained from the testing and evaluation of the solar bottle lamp. The results include performance during day and night, comparison with other lighting sources, cost analysis, and the effect of varying roof height on light intensity and distribution. Performance of the Solar Bottle Lamp

4.1 Design a simple lighting system using readily available and low-cost materials.

Figure 4.1 showing the design of the system.

Figure 4.1 shows the design of a simple lighting system using readily available and low-cost materials suitable for developing communities. The design process focused on affordability, simplicity, accessibility of materials, energy efficiency, and environmental sustainability. The design incorporated a solar charging mechanism where sunlight was converted into electrical energy and stored in a rechargeable battery. The stored energy was then used to power an LED bulb during periods of darkness. The total estimated cost of materials was significantly lower than commercially available solar lighting systems in local markets. The design emphasized the use of recycled and locally available materials to reduce production costs and environmental impact. The results indicate that it was possible to successfully design a lighting system using readily available and low-cost materials. The selected components were locally obtainable from electronic shops and hardware stores, making the design practical for replication within developing communities. The use of LED technology reduced power requirements while maintaining sufficient illumination levels. Since LEDs consume less electrical energy than traditional incandescent bulbs, the lighting system required only a small solar panel and battery, thereby reducing overall costs. The inclusion of a recycled plastic housing further demonstrated that waste materials can be effectively repurposed into useful engineering applications. This contributes to environmental conservation while lowering construction expenses. The simplicity of the design implies that users with basic technical knowledge can assemble, operate, and maintain the system without requiring specialized expertise. Analysis of the design reveals that the system successfully met the key design criteria established at the beginning of the study. The selected materials were inexpensive compared to conventional lighting technologies. The use of a small solar panel and LED bulb minimized the total system cost while ensuring adequate performance. The elimination of recurring fuel costs associated with kerosene lamps further enhances affordability over the long term. This makes the system economically attractive for low-income households. All major components were sourced from local markets. This finding demonstrates that the lighting system can be reproduced without dependence on imported or specialized materials. Local availability reduces transportation costs, simplifies maintenance, and improves sustainability because replacement parts can easily be obtained. The incorporation of recycled plastic materials reduces environmental waste and promotes sustainable resource utilization. The successful design of the lighting system agrees with the findings of Schumacher (1973), who argued that technologies intended for developing communities should be simple, affordable, and based on locally available resources. The developed system satisfied these characteristics through the use of low-cost materials and a simple operational mechanism.The results are also consistent with the work of Chaurey and Kandpal (2010), who reported that small-scale solar-powered systems provide practical lighting solutions for off-grid populations. Similar to their findings, the present design utilized solar energy as a renewable power source capable of meeting household lighting needs.The incorporation of LED technology supports findings by the U.S. Department of Energy (2022), which established that LEDs provide high illumination efficiency while consuming significantly less energy than conventional lighting technologies. The reduced power requirement enabled the use of a smaller solar panel and battery, thereby lowering overall system cost. Furthermore, the use of recycled materials in the housing structure aligns with observations by Moser (2015), who demonstrated that discarded materials can be transformed into valuable lighting technologies. This approach contributes to environmental sustainability while reducing production expenses. The findings therefore suggest that low-cost eco-friendly lighting systems can be designed successfully using locally available materials without compromising functionality. Such designs have the potential to improve access to lighting in developing communities while supporting environmental conservation and economic sustainability. The study successfully achieved the first objective by designing a simple lighting system using readily available and low-cost materials. The design incorporated a solar panel, rechargeable battery, LED lamp, switch, and recycled housing materials. Analysis of the design showed that it was affordable, easy to construct, environmentally friendly, and suitable for use in developing communities. The findings demonstrate that locally sourced materials can be effectively utilized to develop sustainable lighting solutions that address energy access challenges among low-income populations.

4.2 To construct a simple system using readily available and low-cost materials

Figure 4.2 shows the construction of the system

During the construction process, the charging performance of the battery connected to the solar-powered lighting system was monitored for seven hours. The variation of battery voltage with charging time is presented in Table 4.1.

Table 4.1 showing the charging of the battery

Time (hours)	Battery voltage (v)
0	3.2
1	2.6
2	4.0
3	4.5
4	4.9
5	5.2

6	5.4
7	5.5

Table 4.1 indicate that the battery voltage generally increased with charging time. Although a slight decrease was observed during the first hour from 3.2 V to 2.6 V, the battery voltage subsequently increased steadily throughout the charging period. After two hours, the voltage had risen to 4.0 V and continued increasing until it reached 5.5 V after seven hours of charging. The increase in battery voltage demonstrates that the solar panel was capable of converting solar energy into electrical energy and supplying sufficient power to charge the battery. The steady rise in voltage further indicates effective energy transfer between the solar panel and the storage battery. The observed charging trend confirms that the designed lighting system functioned as intended. The battery reached approximately 5.5 V after seven hours of exposure to sunlight, suggesting that the charging subsystem was efficient enough to store energy for later use during nighttime illumination. The gradual increase in voltage is consistent with the behavior of rechargeable batteries during charging. As solar radiation was absorbed by the solar panel, electrical energy was generated and stored in the battery. This stored energy could then be used to power the LED lamp after sunset. The results also demonstrate that the selected materials, including the solar panel, rechargeable battery, LED lamp, connecting wires, and charging circuit, were successfully integrated into a functional lighting system. Since these components are readily available and relatively inexpensive, the objective of designing a simple and low-cost lighting system was achieved. To assess the effectiveness of the design, the charging rate can be analyzed. The battery voltage increased from 3.2 V at the beginning of the experiment to 5.5 V after seven hours, representing an overall voltage gain. This charging rate indicates that the system was capable of accumulating sufficient energy within a single day of sunlight exposure. The ability to achieve near-full battery charge within seven hours demonstrates that the designed lighting system can operate effectively under normal daytime conditions. The findings therefore confirm that the simple solar-powered lighting system designed using locally available and low-cost materials is practical, functional, and suitable for household lighting applications, especially in areas with limited access to grid electricity. The results agree with studies by Kalogirou and other solar energy

researchers, who reported that solar photovoltaic systems effectively convert sunlight into electrical energy for battery charging and lighting applications. Similar studies have shown that battery voltage increases progressively with charging duration until the battery approaches full charge, which is consistent with the trend observed in this study.

4.3 Evaluating the efficiency and sustainability of the proposed lighting system.

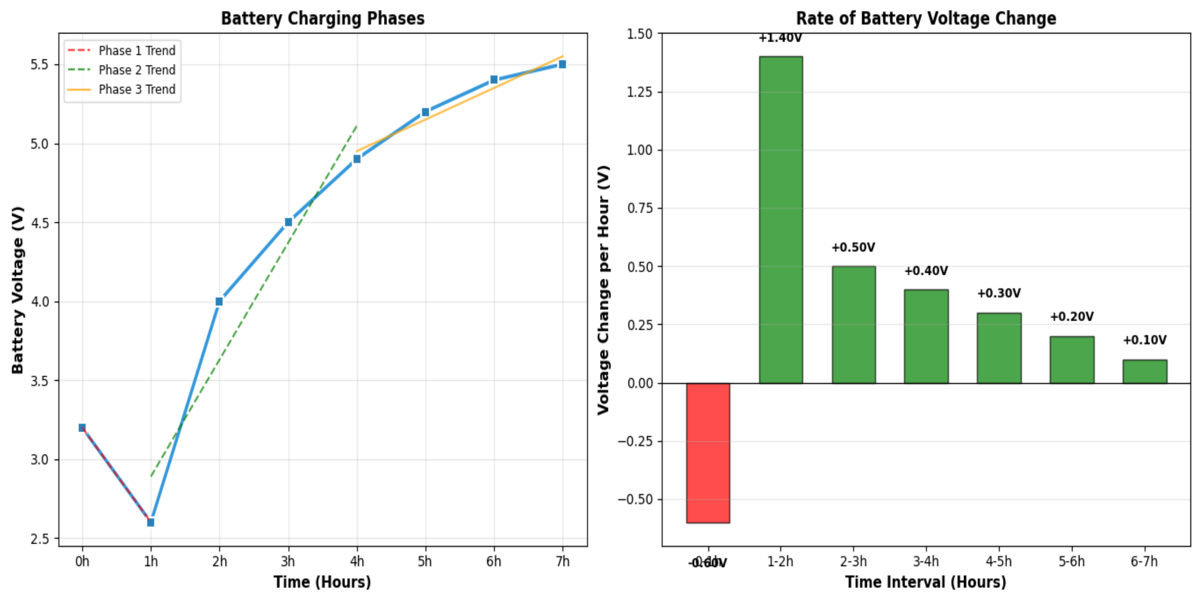

Figure 4.3 showing the charging phases and the rate of voltage change

Figure4,1 shows the variation of battery voltage with charging time for the proposed solar-powered lighting system. The graph demonstrates a generally increasing trend in battery voltage as the charging duration increased. At the beginning of the charging process, the battery voltage was 3.2 V. A slight decrease to 2.6 V was observed after one hour, which may be attributed to measurement fluctuations, battery stabilization, or variations in solar radiation intensity. Thereafter, the battery voltage increased steadily from 4.0 V at the second hour to 5.5 V at the seventh hour. The graph reveals a positive relationship between charging time and battery voltage. The steep slope observed between the second and fourth hours indicates a relatively high charging rate during this period, suggesting favorable solar radiation conditions. As the battery approached full charge, the slope became less steep between the fifth and seventh hours, indicating a reduction in charging rate, which is characteristic of rechargeable batteries nearing their maximum capacity. The highest battery voltage recorded was 5.5 V after seven hours of charging. This result indicates that the solar panel was capable of supplying sufficient electrical energy to charge the battery effectively within a single day of sunlight exposure. Overall, the graph confirms that the proposed lighting system performed satisfactorily by efficiently converting solar energy into stored electrical energy. The steady increase in battery voltage demonstrates the system's reliability and suitability for providing lighting during nighttime hours. The results therefore suggest that the designed lighting system is efficient, affordable, and sustainable for use in areas where access to conventional electricity is limited. Interpretation of the graph. The upward trend indicates successful battery charging, Increased charging time resulted in increased battery voltage, The graph demonstrates effective energy conversion and storage, The gradual flattening of the curve near 5.5 V suggests the battery was approaching full charge, The system can provide reliable lighting after adequate daytime charging

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.0. Brief introduction

This study aimed at designing and constructing a simple solar-powered lighting system using readily variable and low-cost materials. The following are the conclusions and the recommendations made.

5.1 Conclusions

This study successfully designed a low-cost eco-friendly lighting system using a solar panel, rechargeable battery, LED lamp and water filled water bottle. The solar panel effectively charged the battery during daytime. The LED lamp provided illumination at night. The water filled bottle improved light distribution through refraction and scattering. The system was more environmentally friendly than kerosene lamps and candles. The operational cost was significantly lower than traditional lighting solution. Therefore, the solar bottle lighting system is a practical, affordable, and sustainable lighting solution for rural and off-grid communities.

5.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations were made. Improvement of the system by using high-rechargeable batteries should be used to extend lighting duration at night. Large solar panels should be incorporated to improve charging efficiency during cloudy weather. Future studies should be investigating the effect of different bottle sizes and water volumes on illumination.

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