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Design and Development of the Portable Solar Fan

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Abstract

The demand for sustainable and portable cooling solutions has grown significantly with rising global temperatures and increased outdoor activity. Traditional electric-powered fans often lack mobility and rely heavily on non-renewable energy sources, creating a need for more environmentally friendly alternatives. This project addresses that gap by designing and developing a portable solar-powered fan that emphasizes energy efficiency, ease of transport, and user comfort. The objective is to create a device that utilizes solar energy to provide consistent airflow for personal cooling, particularly in off-grid or outdoor settings. The fan was developed through a structured design process, selecting lightweight and durable materials, integrating a solar panel, and including a rechargeable battery system. Several design iterations and experimental testing were evaluated based on battery life, structural integrity, and ergonomic handling. Results indicate that with a full charge of 5 bars, the battery provides a total runtime of approximately 11.92 hours. Also, the charging characteristic of the battery is notably efficient, approximately 53 minutes to charge, resulting in a total charging time of around 4.42 hours from empty to full. During operation, the battery maintains a stable voltage output within the range of 12V to 12.5V. The design successfully balances functionality and portability, although improvements are needed in structural rigidity. In conclusion, the portable solar fan demonstrates a practical application of renewable energy in daily-use appliances and highlights potential for further development in sustainable consumer product design.

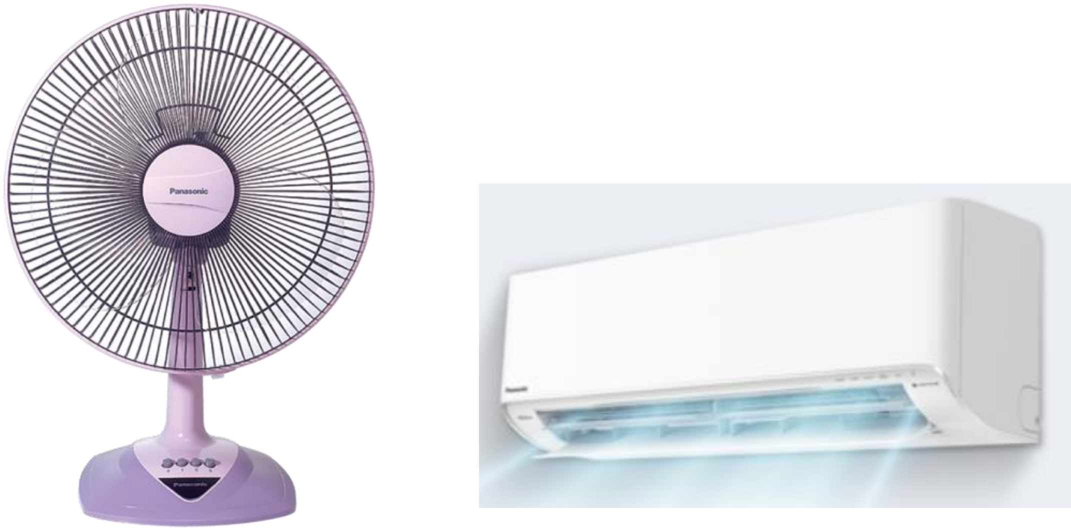
1. Introduction

Malaysia's climate is consistently hot and humid, often exceeding 30°C. This heat leads to discomfort, reduces productivity, and in extreme cases, causes heat-related illnesses. In rural and low-income communities, access to air conditioning is limited, making the effects of high temperatures more severe. As global warming continues to worsen, there is an urgent need for more sustainable and accessible cooling solutions to ensure public well-being [1].

As shown in Fig. 1(a) and Fig. 1(b), Malaysia's most common cooling devices are electric fans and air conditioners [2][3]. Although effective indoors, both require consistent electricity access, limiting their use in outdoor or off-grid settings. Air conditioners also consume high energy, increasing carbon emissions and utility costs. Solar-powered fans provide a greener option, but today's models lack portability, weak airflow, poor efficiency, and low durability [4].

Malaysia's strong solar potential, with daily solar irradiance ranging from 4.21 to 5.56 kWh/m^2, supports using solar technologies [5]. At the same time, the global off-grid solar systems market is projected to grow significantly from approximately USD 2.74 billion in 2024 to about USD 17.42 billion by 2030, driven by rising energy needs in areas without reliable grid access. These trends indicate strong commercial potential for portable solar cooling devices that are efficient, durable, and suited to outdoor use [6].

Designing a portable solar fan is also a valuable educational opportunity for engineering students. It provides hands-on experience in mechanical design, thermal management, electrical systems, and energy efficiency. The project's interdisciplinary nature aligns with Malaysia's Technical and Vocational Education and Training (TVET) goals and fosters innovation. Additionally, it supports international efforts such as the United Nations Sustainable Development Goal 7 (SDG 7) for clean and affordable energy [7][8].



(a) (b)

Fig. 1 *Common Cooling Devices (a) Electrical Fan; (b) Air Conditioner*

1.1 Problem Statement

Despite growing interest in solar solutions, most portable solar fans still underperform outdoors. Common problems include portability, low airflow, insufficient battery capacity, and unreliable solar charging systems. These limitations significantly reduce the fan's practicality when dependable cooling is crucial [9].

This lack of reliability becomes a serious concern for those depending on these fans during blackouts or when working in hot, outdoor environments. When cooling devices fail in such scenarios, users may experience discomfort and health risks. These failures impact individuals and hinder the broader acceptance of solar-powered technologies. In the long term, such problems weaken public confidence in renewable energy products.

The consequences of ineffective solar fans are especially serious for rural communities, older people, construction workers, street vendors, and groups often exposed to high heat without reliable cooling options. Without dependable portable solutions, they face daily risks to their comfort, productivity, and safety. The limited availability of functional products also slows Malaysia's national push toward cleaner energy solutions.

Therefore, there is a clear need to design a portable solar fan that performs well in real outdoor conditions. It should provide stronger airflow, improved battery life, and durable construction to suit Malaysia's tropical climate. This project aims to develop a user-friendly, efficient, and reliable portable solar fan that meets current shortcomings and supports wider adoption of sustainable cooling technology.

1.2 Literature Review

Fans have been used for thousands of years, starting from manual handheld fans in ancient Egypt. In 1882, electric fans were introduced with the help of early electric motors, and by the early 1900s, they became common household items. Over time, fan designs improved with features like speed control and safety covers. The invention of solar cells in the 1950s allowed fans to be powered by sunlight, and today, solar-powered portable fans are widely used in areas where grid electricity is unavailable [10][11][12].

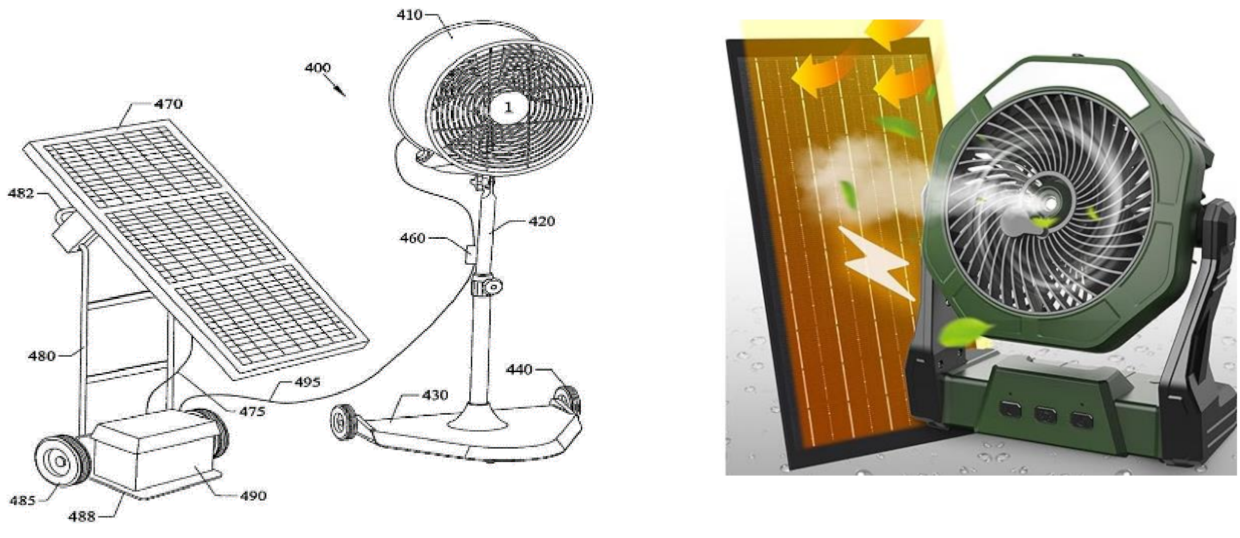
Ventilation is crucial in cooling outdoor environments by helping remove hot air and increasing comfort. Natural airflow alone is usually insufficient in countries like Malaysia, where the average temperature often exceeds 30°C and high humidity levels. Fans create air movement that helps sweat evaporate from the skin, reducing the body's heat and improving thermal comfort. This condition is especially helpful in outdoor places such as markets, events, or construction sites where fresh airflow is limited [1].

There are several types of ventilation systems used outdoors. Manual fans are basic and don't require power, but need physical effort to use. Battery-powered fans can run for 3 to 6 hours and are useful for short-term cooling, depending on the battery size, usually 2,000–5,000 mAh [13]. Solar-powered fans use energy from the sun and can run for about 8 to 12 hours on a full charge using solar panels. Some models combine solar and battery power to work day and night, providing more flexibility for outdoor users [14].

Several existing solar fan projects and commercial products show different design approaches. A notable example of a high-performance solar fan is the High Efficiency Solar Powered Fans designed by Danny S. Parker and Bart Hibbs, as presented in Fig. 2(a). This system uses 15-inch diameter twisted blades and operates with a 16-watt DC motor, producing approximately 1,040 cubic feet per minute (CFM) of airflow at around 500 RPM. The design emphasizes energy efficiency by balancing airflow output with low power usage, making it suitable for stationary outdoor environments. However, the entire setup is mounted on an L-shaped wheeled frame and includes a large solar panel and battery tray, which limits its portability. This highlights the trade-off between ventilation performance and user mobility, reinforcing the importance of compact and lightweight fan designs in future applications [15].

Many commercial solar fan models currently available online offer a balance between cost, portability, and functionality, as one example is depicted in Fig. 2(b). These fans generally include 10 to 30-watt solar panels, integrated rechargeable batteries, USB charging ports, and foldable plastic or ABS frames. These products are favored for personal outdoor use due to their convenience and ease of transport. However, their simple design often sacrifices airflow power and structural durability, suggesting opportunities for improvement in fan blade design and energy storage efficiency [16][17].

A typical portable solar fan consists of three key systems: the frame, the main mechanism, and the support mechanism. The frame is usually made from lightweight but durable materials like ABS plastic to make the fan easier to carry. The main mechanism includes the fan blades, solar panel, and motor. The support mechanism contains stands, switches, battery compartments, and sometimes USB ports for extra functionality. All parts must work together to ensure the fan is durable, easy to use, and effective in various outdoor conditions [14].



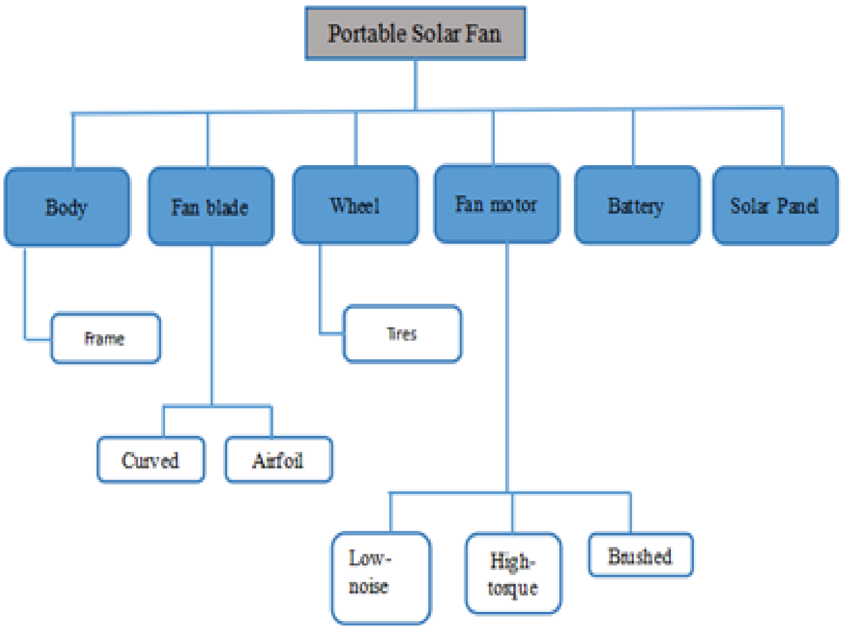
(a) (b)

Fig. 2 *Solar Fan (a) Patented product; (b) Commercial product*

2. Methodology

This project's development is presented in Fig.3 (a) below. The project begins with defining the research problem, where the core issue is identified based on current needs or challenges relevant to the field. This step ensures the project's direction is grounded in addressing a real-world problem. Following this, research objectives are formulated to outline the specific aims and expected outcomes. These objectives guide the project process, ensuring each stage aligns with the overall purpose.

A comprehensive literature review is then conducted to examine existing technologies, previous projects, and theoretical foundations related to the project topic. This step provides context, identifies knowledge gaps, and supports the justification for the project's development. The next phase involves the sketch design of the project, where conceptual drawings or models are developed. This design stage helps visualize the proposed system's structure, components, and functionality, as the foundation for technical implementation. In addition, the Weighted Rating Method is conducted. The alternative is analyzed, and the finalized Product Component Decomposition is developed based on the best concept for the project, as shown in Fig. 3(b).



(a) **(b)**

Fig. 3 *Portable Solar Fan Project (a) Design and Development Flow Chart; (b) Product Component Decomposition*

Subsequently, data analysis is performed to evaluate the performance or feasibility of the design. This may involve simulations, testing, or benchmark comparisons to derive meaningful insights. Based on the analysis, recommendations are made to improve design efficiency, usability, or performance. These recommendations ensure the project meets both technical and practical expectations. The results section presents the final findings and outcomes, reflecting the degree to which the project objectives have been achieved. The workflow concludes with the completion of the project, marking a systematic progression from problem identification to a working solution backed by analysis and evidence.

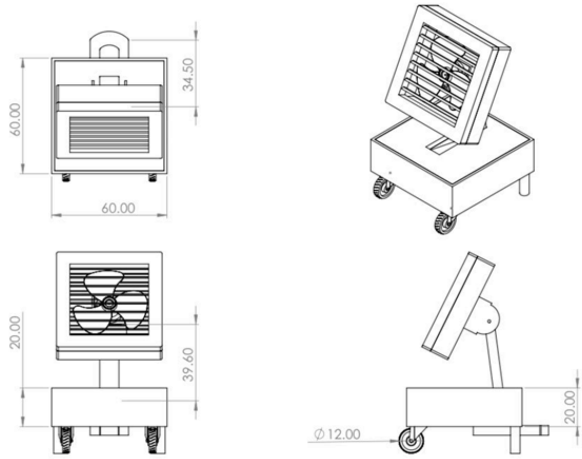
2.1 Material Selection

The image illustrated by Fig. 4(a) and Fig. 4(b) is the Orthographic Drawing and the Bill of Materials (BOM) for a 3D Solid Works drawing of the Portable Solar Fan. The drawing includes an exploded isometric view of the assembly and a detailed parts list table. Each part is labeled with an item number (ITEM NO.), material specification, and quantity, providing a clear reference for fabrication and assembly.

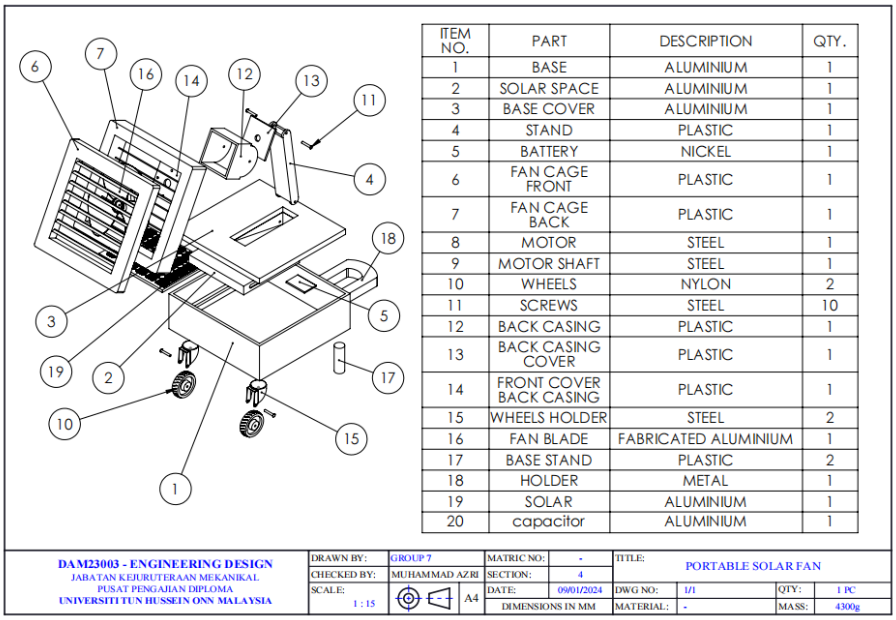
The fan structure primarily comprises aluminum, plastic, steel, and nickel components, selected based on properties like weight, strength, corrosion resistance, and cost-effectiveness. Key structural parts include the base (Item 1), solar space (Item 2), and fan blade (Item 17), with aluminum chosen for its lightweight and durability. The stand (Item 4) and casing components (Items 11–13) are made of plastic, offering insulation and ease of manufacturing.

Mechanical and electrical functionality is supported by components like the motor (Item 8), solar panel (Item 19), battery (Item 5), and capacitor (Item 20). The motor shaft (Item 9) and screws (Item 10) are made of steel for structural integrity and load transmission. The solar panel enables off-grid operation by charging the battery, making the system energy-efficient and environmentally friendly.

This comprehensive BOM includes 20 individual parts, with all items listed as quantity 1, indicating a single unit of each is required per assembly. The drawing ensures the assembly process is systematic and traceable, providing clarity to manufacturers and technicians during production.



(a)



ITEM NO.	PART	DESCRIPTION	QTY.
1	BASE	ALUMINIUM	1
2	SOLAR SPACE	ALUMINIUM	1
3	BASE COVER	ALUMINIUM	1
4	STAND	PLASTIC	1
5	BATTERY	NICKEL	1
6	FAN CAGE FRONT	PLASTIC	1
7	FAN CAGE BACK	PLASTIC	1
8	MOTOR	STEEL	1
9	MOTOR SHAFT	STEEL	1
10	WHEELS	NYLON	2
11	SCREWS	STEEL	10
12	BACK CASING	PLASTIC	1
13	BACK CASING COVER	PLASTIC	1
14	FRONT COVER BACK CASING	PLASTIC	1
15	WHEELS HOLDER	STEEL	2
16	FAN BLADE	FABRICATED ALUMINIUM	1
17	BASE STAND	PLASTIC	2
18	HOLDER	METAL	1
19	SOLAR	ALUMINIUM	1
20	capacitor	ALUMINIUM	1

(b)

Fig. 4 *Portable Solar Fan Drawings (a) Orthographic; (b) BOM (Bill of Materials)*

2.2 Mathematical Equation

A system design analysis is essential to evaluate whether the performance of the Portable Solar Fan meets the required specifications. The design's performance can be assessed through three main approaches: analytical methods, experimental testing, or a combination of both. This study conducted fundamental calculations to determine the system's power and energy output. These parameters are crucial for understanding the efficiency and effectiveness of the solar-powered fan under operational conditions. Below are the mathematical equations used to analyze the criteria:-

i. Power, P

$$P = V.I \tag{1}$$

Where:-

P = Power
V = voltage
I = current

ii. Energy, E

$$E = V.Q \quad (2)$$

Where:-
P = Energy
V = voltage
Q = charge

3. Results and Discussion

3.1 Product Specification

The Portable Sports Post has undergone several meticulous manufacturing processes to produce a high-quality product. These duties include measuring, cutting, machining, and welding. These processes start with precise measuring, where accurate dimensions of raw materials and components are ensured using precision tools like measuring tape and callipers.

Table 1 *Portable Solar Fan Specification*

No.	Details	Specification
1	Base size	50 cm x 43 cm x 14 cm
2	Weight	6 kg
3	Tyres	4 pcs
4	Transportation (movement)	Carry using the handle at the top of the fan

Table 1 above presents the key physical specifications of the Portable Solar Fan. The unit's base measures 50 cm in length, 43 cm in width, and 14 cm in height, providing a stable footprint for outdoor use. The total weight of the device is approximately 6 kg, which allows for manageable portability. The system has four tyres to facilitate movement, enhancing mobility on various surfaces. Additionally, the fan includes a handle at the top, enabling users to carry the unit easily when wheels are unsuitable, such as on stairs or uneven terrain.

3.2 Wiring Configuration

Fig. 5 below illustrates the basic wiring configuration of the Portable Solar Fan system. The setup includes a solar panel connected to a charge controller, which regulates the power flow to a rechargeable battery. The battery then supplies energy to the fan. This configuration ensures that solar energy is efficiently stored and utilized to operate the fan.

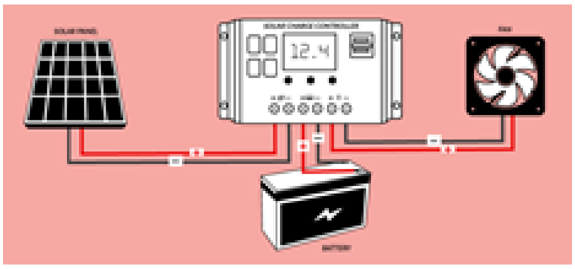


Fig. 5 *Portable Solar Fan Wiring Configuration*

3.3 Prototype Testing and Result Analysis

The product performance analysis, as in Fig. 6(a), is intended to analyze the endurance and charging characteristics of the battery, emphasizing operational metrics and recommended maintenance practices. Under typical usage conditions, the battery endurance is approximately 2 hours and 23 minutes per bar, totaling around 143 minutes. With a full charge of 5 bars, the battery provides a total runtime of approximately 11.92 hours, making it suitable for extended use without frequent recharging.

Also, the charging characteristic of the battery is notably efficient, approximately 53 minutes to charge, resulting in a total charging time of around 4.42 hours from empty to full. This relatively short charging duration lets users quickly restore full battery capacity and maintain productivity with minimal downtime. During operation, the battery maintains a stable voltage output within the range of 12V to 12.5V. This consistent voltage regulation ensures reliable performance of the connected device and reflects the battery's good electrical stability, contributing to both system safety and component longevity.

To maximize battery lifespan, it is recommended to recharge the battery after using it for no more than 2 bars. Limiting deep discharge cycles helps preserve the battery's capacity over time. This approach offers a practical balance between performance and durability. For example, using the battery up to 2 bars provides approximately 4 hours and 46 minutes before recharging, minimizing battery stress and supporting long-term reliability.

During the Portable Solar Fan assembly, all components were verified to be fully functional. As presented by Fig. 6(b), the wheels with integrated brakes operate effectively, ensuring stable positioning during use. The wiring system is properly connected, allowing the fan to function as intended. The fan stand has also been constructed to provide reliable support and maintain overall stability during operation.

As in Fig. 6(c), structure stability analysis on the fan stand has identified a significant issue: the fan stand does not maintain stability when the fan is turned on. Additional support, such as a rope, is necessary to address this instability. This supplementary support will anchor the fan stand, preventing movement and ensuring the fan remains stable. This adjustment is crucial for ensuring the safety and functionality of the portable solar fan, particularly during its operation.

(a) (b) (c)

Fig. 6 *Prototype Testing (a) Performance Test; (b) Component Functionality Test; (c) Structure Stability Test*

4. Conclusion and Recommendations

In conclusion, the portable solar fan demonstrates a practical application of renewable energy in daily-use appliances and highlights potential for further development in sustainable consumer product design. The project successfully designed a solar fan to be portable, lightweight, and user-friendly. Performance testing confirmed the efficiency of the solar panel and wiring system in harvesting solar energy and the reliability of the battery, which indicates that with a full charge of 5 bars, the battery provides a total runtime of approximately 11.92 hours. Also, the charging characteristic of the battery is notably efficient, approximately 53 minutes to charge, resulting in a total charging time of around 4.42 hours from empty to full. During operation, the battery maintains a stable voltage output within the range of 12V to 12.5V. The design successfully balances functionality and portability, although improvements are needed in structural rigidity.

For future development, exploring advanced battery technologies that offer greater storage capacity and faster charging times is recommended to enhance overall energy efficiency. High-efficiency solar panels can improve energy absorption, particularly in low-light conditions. Additionally, designing a more user-friendly interface will simplify operation and allow users to monitor battery status more easily. Improving the structural durability of both the fan and solar panel stand will ensure reliable performance in diverse outdoor environments. Lastly, integrating an intelligent energy management system will help optimize power distribution, reduce energy waste, and extend the battery's lifespan.

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Conflict of Interest

This publication has no conflicts or issues regarding the data, as it relies on references from the internet and research.

Author Contribution

The authors confirm their contribution to the paper as follows: ***Problem, conception, and design study:*** *Muhammad Danial Asyraf, Muhammad Hud Zakwan, Mohd Najib;* ***Prototype Manufacturing and Data collection:*** *Muhammad Danial Asyraf, Muhammad Hud Zakwan, Nurul Asma Aqilah;* ***Analysis and interpretation of results:*** *Muhammad Danial Asyraf, Muhammad Hud Zakwan, Nurul Asma Aqilah;* ***Draft manuscript preparation:*** *Muhammad Danial Asyraf, Nurul Asma Aqilah, Mohd Najib Janon, Mahmod Abd Hakim, Hafsa Mohammad Noor. All authors reviewed the results and approved the final version of the manuscript.*

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