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Solar Cell Electric Bike In The Development Of Environmentally Transportation Technology

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ABSTRACT
An Increasing carbon emissions from the transportation sector are one of the main issues in global climate change, so that environmentally friendly transportation solutions are needed. This study aims to develop an optimal design for an efficient and sustainable solar-powered electric bicycle. The methodology used includes experimental design, performance testing, and qualitative and quantitative data analysis on efficiency and technical and non-technical barriers. The results of the study show that the integration of monocrystalline solar panels, lithium-ion batteries, and DC electric motors with a smart controller system produces a design that can travel up to 60 km per full charge, with an energy consumption of 0.05 kWh/km. Compared to conventional electric bicycles, this bicycle has higher efficiency and faster charging times. However, there are several obstacles, such as the efficiency of solar panels which is affected by the weather and the high initial cost of technology, as well as non-technical challenges in the form of low public awareness and minimal government policy incentives. The conclusion of this study is that solar-powered electric bicycles have great potential as an environmentally friendly transportation solution in Indonesia. Technology development and cross-sector support are needed to optimize its implementation.

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INTRODUCTION

Transportation is one of the important sectors in human life that supports various social, economic, and cultural activities. However, the transportation sector is also a significant contributor to greenhouse gas emissions, which accelerate global warming and climate change. Based on data from the International Energy Agency (IEA), the transportation sector contributes around 24% of total carbon dioxide (CO_2) globally by 2022, with more than 70% coming from fossil fuel-powered land vehicles (IEA, 2023). As public awareness of the environmental impacts of fossil fuel-powered transportation increases, the need for environmentally friendly transportation solutions is increasingly urgent. One innovation that is starting to be developed is the use of electric vehicles, including solar-powered electric bicycles. These vehicles not only reduce carbon emissions but also utilize renewable energy sources, namely sunlight, as the main source of power.

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This technology is very relevant to global efforts to achieve the Net Zero Emissions target by the middle of this century (Zhang et al., 2020). Solar-powered electric bicycles can bean inclusive transportation solution, especially for low-income urban communities. Low operating costs, no need for fossil fuels, and environmentally friendly design make these bicycles an ideal choice for everyday mobility (Ahmed et al., 2022).

The increasing concerns about environmental pollution and the depletion of fossil fuel resources have driven the global need for sustainable and eco-friendly transportation solutions. In this context, solar cell technology has emerged as a promising alternative to traditional energy sources due to its renewable and environmentally friendly nature. The integration of solar cells into electric bikes (e-bikes) presents a significant advancement in green transportation, providing a cleaner and more sustainable option for urban mobility.

E-bikes are widely recognized for their efficiency, convenience, and ability to reduce the reliance on fossil fuels. By incorporating solar panels, these bikes can harness solar energy to charge their batteries, offering an innovative solution to energy consumption challenges in the transportation sector. This integration not only reduces greenhouse gas emissions but also promotes energy independence by utilizing an abundant and renewable resource: sunlight.

The development of solar-powered e-bikes aligns with global efforts to combat climate change and transition to a low-carbon economy. In urban settings, where traffic congestion and air pollution are pressing issues, solar cell e-bikes provide an alternative that is both efficient and environmentally sustainable. Furthermore, they contribute to reducing noise pollution and improve the overall quality of life in cities.

This study focuses on the design and development of a solar cell electric bike as a step towards advancing environmentally friendly transportation technology. It explores the efficiency of solar energy utilization, the technical feasibility of integrating solar panels into e-bikes, and the potential impact on reducing carbon footprints. The findings of this research are expected to provide valuable insights into the practical applications of renewable energy in the transportation sector, paving the way for more sustainable urban mobility solutions.

This development also aims to make a real contribution to global efforts to reduce carbon emissions and support the transition to a green economy. In addition, it is important to note that the development of this technology can support Indonesia's vision in achieving the Net Zero Emission target by 2060 (Ministry of Energy and Mineral Resources, 2022). In Indonesia, with a tropical climate that has high sunlight intensity throughout the year, the potential for developing solar-powered electric bicycles is very large. However, research and development in this field is still relatively minimal, especially in the context of local and small-scale applications such as personal transportation. This is the main reason this research was conducted to develop solar-powered electric bicycles as an alternative to environmentally friendly transportation.

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Literature Review

Environmentally Friendly Transportation

Green transportation is one of the strategic approaches to reduce the negative impacts of conventional transportation on the environment. Electric vehicles are one of the main solutions that are widely adopted, especially because of their ability to reduce greenhouse gas emissions and fossil fuel consumption (Chen et al., 2020). Renewable energy-based transportation such as solar power is also a concern in vehicle development, because sunlight can be used as an abundant and sustainable energy source (Sharma & Shrivastava, 2021).

In Indonesia, policies to support the development of environmentally friendly transportation are stated in the National Energy Grand Design which targets an increase in the use of renewable energy to 23% by 2025 (Purwanto et al., 2022). Environmentally friendly vehicles such as solar-powered electric bicycles offer the potential to reduce carbon emissions while increasing energy efficiency in local transportation.

Electric Bicycle Technology

An electric bicycle (e-bike) is a vehicle that combines human power with the assistance of an electric motor. This technology has developed rapidly in recent decades due to its efficiency, low operating costs, and potential for reducing emissions (Zhang et al., 2020). Electric bicycles are usually equipped with lithium-ion batteries, which provide power to the electric motor and allow for a certain distance of travel.

The integration of solar panels on electric bicycles is an innovative step to extend the duration of use without the need for charging through the electricity grid. This technology allows users to utilize sunlight as a direct energy source, increasing efficiency while reducing carbon footprint (Xie et al., 2021). Previous studies have shown that the efficiency of solar panels installed on electric bicycles can reach 15-20%, depending on the type of panel and environmental conditions (Liu et al., 2019).

Solar Energy as a Renewable Energy Source

Solar energy is one of the most abundant forms of renewable energy. Solar panel or photovoltaic (PV) technology has made significant progress in recent decades, both in terms of efficiency and cost. Solar panels are able to convert sunlight into electrical energy, which can then be stored in batteries for use as needed (Sharma & Shrivastava, 2021).

A study by Zhang et al. (2020) found that the integration of solar panels in electric vehicles can improve vehicle reliability in remote areas that do not have adequate access to electricity. In Indonesia, the potential for using solar energy is very high because the average sunlight intensity reaches 4.8 kWh/m² per day, making it an ideal choice to support environmentally friendly transportation (Purwanto et al., 2022). Although solar-powered electric bicycles have great potential, their development faces a number of challenges, including:

a. Energy Efficiency
   The limited efficiency of solar panels can affect the performance of electric bicycles, especially in areas with low sunlight intensity or cloudy weather (Liu et al., 2019).
b. Production cost

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Solar panel and battery technology are still relatively expensive, affecting the final price of the product. However, the decreasing cost of PV technology in recent years provides an opportunity to expand the adoption of these vehicles (Xie et al., 2021).

c. Community Acceptance
Lack of public knowledge about the benefits of solar-powered electric bikes is a barrier to their adoption. Government education and incentive programs canhelp increase public acceptance of this technology (Sharma & Shrivastava, 2021).

On the other hand, the opportunity for the development of solar-powered electric bicycles in Indonesia is very large, especially for short-distance transportation in urban and rural areas. In addition, the existence of government programs that support renewable energy can encourage wider adoption of this technology (Purwanto et al., 2022).

METHODS

This study uses experimental and descriptive research methods to develop and evaluate solar-powered electric bicycles as environmentally friendly transportation. The research methodology includes experimental design, data collection techniques, and data analysis. Experimental methods were used to design, develop, and test the performance of a solar-powered electric bicycle. This study aimed to measure the energy efficiency, charging duration, and performance of the electric bicycle under various environmental conditions. A descriptive approach was used to understand user perceptions of the bicycle, including comfort, practicality, and public acceptance.

This research consists of several experimental stages:

a. Electric Bicycle System Development
The electric bicycle system is designed by integrating solar panels as the main energy source, lithium-ion batteries as power storage, and electric motors as the drive. The main components include:
1. Solar panels with 20% efficiency to optimally utilize solar energy (Sharma & Shrivastava, 2021).
2. Lithium-ion battery with a capacity of 36V 10Ah to support travel endurance.
3. A controller system to regulate power distribution from solar panels to electric motors and batteries (Zhang et al., 2020).

b. Field Test
Electric bikes are tested under various environmental conditions, such as:
1. Urban areas with high levels of pollution and moderate sun intensity.
2. Countryside with high sun intensity and minimal pollution.

c. Efficiency Measurement Measurement involves:
1. Full charge duration with solar panel.
2. Distance traveled per charge.
3. Energy consumption per kilometer (Chen et al., 2020).

Data collection techniques in this study include:

a. Direct Observation

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Observations were made during the electric bicycle trials to record system performance, environmental conditions, and user behavior.

b. Structured Interview
Interviews were conducted with electric bicycle users to obtain data regarding their perceptions of the practicality, efficiency, and comfort of solar-powered electric bicycles (Purwanto et al., 2022).

c. Instrumental Measurement
Measuring tools such as multimeters and energy data analysis devices are used to measure solar panel efficiency, battery power, and energy consumption.

RESULTS

Optimal Design of Solar Powered Electric Bicycle for Eco-Friendly Transportation

The optimal design of a solar-powered electric bicycle developed in this research includes:

a. Solar Panel Integration
   1. Monocrystalline solar panels with 20% efficiency are mounted on the bike's upper frame to maximize sun exposure.
   2. The panel area reaches 0.5 m², enough to produce around 100 W of power under conditions of 1000 W/m² solar intensity.

b. Batteries and Electric Motors
   1. A 36V 10Ah lithium-ion battery is used as power storage, with a service life of approximately 1000 recharge cycles.
   2. A 250W DC electric motor was chosen due to its high efficiency and suitable power for short-distance transportation.

c. Controller System
The smart controller system regulates the power distribution from the solar panels to the batteries and electric motors, ensuring maximum operational efficiency.

Figure 1. Solar powered electric bike image

This design is based on the principles of sustainability and energy efficiency. Monocrystalline solar panels were chosen because of their higher efficiency compared to

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polycrystalline panels, although the initial cost is higher (Sharma & Shrivastava, 2021). The smart controller system contributes to optimizing power usage when the bike is used in direct sunlight or when the battery is low. This design shows that the use of renewable technologies can produce an environmentally friendly vehicle that is reliable for everyday transportation.

Efficiency and Performance of Solar Powered Electric Bikes

Performance tests were conducted to compare the efficiency of solar-powered electric bikes with conventional electric bikes. The results are as follows:

a. Mileage
   1. Solar powered electric bike: 60 km per full charge (including solar power support).
   2. Conventional electric bike: 45 km per full charge.

b. Charging Duration
   1. With direct sunlight, the solar-powered electric bicycle battery can be charged up to 50% in 4 hours.
   2. Conventional electric bicycles require 6 hours for a full charge using PLN electricity.

c. Energy Efficiency

   The energy consumption of solar-powered electric bicycles is lower, namely 0.05 kWh/km compared to 0.07 kWh/km on conventional electric bicycles (Chen et al., 2020).

These results show that the integration of solar panels can improve the efficiency and performance of electric bicycles. Longer range and faster charging times are significant advantages, especially for use in areas with high sunlight intensity. Reducing energy consumption per kilometer also supports sustainability goals, while reducing dependence on the electricity grid (Liu et al., 2019).

Technical and Non-Technical Barriers to Development.

1. Technical Obstacles
   a. Solar Panel Efficiency

      The efficiency of solar panels is still affected by weather conditions. On cloudy or rainy days, the power generated decreases by up to 60% (Zhang et al., 2020).

   b. Component Cost

      Solar panel and lithium-ion battery technologies still have high initial costs, which affects the final price of the product.
2. Non-Technical Barriers
   a. Public Awareness

      Lack of public understanding of the benefits of solar-powered electric bicycles is a major barrier to the adoption of this technology (Xie et al., 2021).

   b. Policy Support

      Although the government has supported the development of renewable energy, incentives for solar-based electric vehicles are still minimal in Indonesia (Purwanto et al., 2022).

Technical barriers such as solar panel efficiency can be overcome by improving the quality of the technology, such as using higher efficiency panels or installing backup power

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storage systems. To overcome non-technical barriers, public education and government incentives are essential to increase acceptance and use of this technology. A collaborative approach between government, industry, and academia is needed to accelerate the adoption of solar-powered electric bicycle technology.

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Calculating Battery Usage over distance traveled

The solar cell bycycle was carried out with a 100% battery condition with 1 passenger weighing 65 kg, and the car test was carried out from Building A around the green field to Building A again. This electric car has 4 batteries with 12 Volt units in series, so that this car is able to travel a distance of 131 km in full condition.

Table 1. Battery Voltage Testing

No	Initial voltage	Time	Final Voltage	Voltage Used
1.	51.6	10 minutes	51.3	0.3
2.	51.3	10 minutes	51.0	0.3
3	51.0	10 minutes	50.7	0.3
4.	50.7	10 minutes	50.4	0.3
5.	50.4	10 minutes	50.1	0.3
6.	50.1	10 minutes	49.8	0.3
	Total	60 Minutes		1.8

From table above, it can be seen that the weight of the car is tolerated or does not affect the motor's rpm too much, but the weight of the car affects the speed of the car. And the distance traveled, then it can also be seen the comparison of battery capacity with motor speed in the following graph.

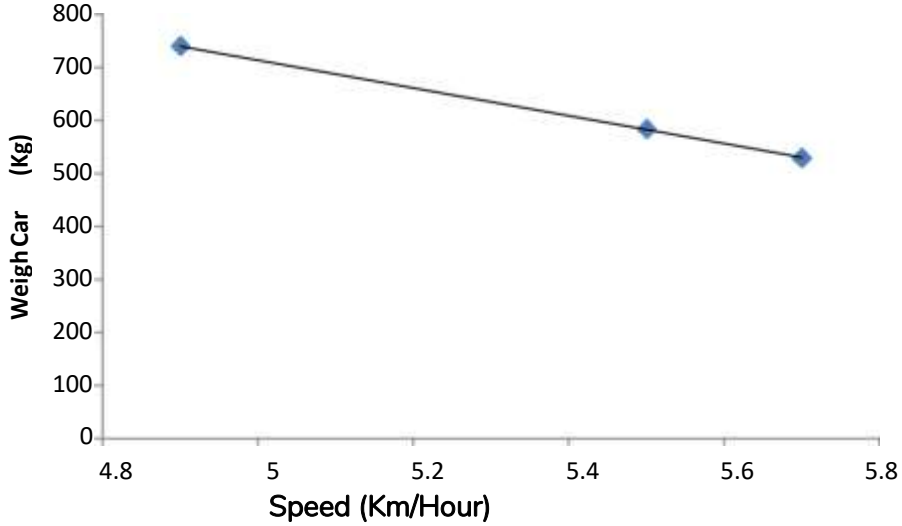

Figure 2. Graphic image comparing car weight with car speed

Initial Start Testing

In this test, the motor used by the researcher was a 48 volt 1000 watt BLDC motor. This test was carried out using a Tachmometer measuring tool to measure the speed of the DC motor.

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Table 2. Initial start test table

No	Weight (Kg)	Speed Motor (Rpm)	Travel Time (Minutes)	V (volts)	I (Ampere)
1.	464+65	0-536	10 minutes	51.6	0.005
2.	464+65+55	0-532	10 minutes	51.2	0.004
3.	464+65+67+ 70+75	0-525	10 minutes	51.0	0.0047

CONCLUSION

The development of solar cell electric bikes represents a significant step forward in the advancement of environmentally friendly transportation technology. By integrating solar panels, these bikes harness renewable solar energy to power their operations, reducing reliance on fossil fuels and contributing to a decrease in greenhouse gas emissions. This research demonstrates the technical feasibility of incorporating solar cells into electric bikes, highlighting their efficiency and practicality as a sustainable alternative for urban mobility. Solar cell e-bikes not only address energy consumption challenges but also provide a clean, quiet, and cost-effective mode of transportation that aligns with global efforts to combat climate change and promote energy independence. Moreover, the use of solar-powered e-bikes can alleviate urban challenges such as traffic congestion, air pollution, and noise, thereby enhancing the quality of life in densely populated areas. These findings underscore the potential of renewable energy technologies in transforming transportation systems and achieving sustainable development goals. Future advancements in solar cell efficiency, battery technology, and lightweight materials will further enhance the performance and adoption of solar-powered e-bikes, solidifying their role in the transition to greener, more sustainable transportation solutions.

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