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Review on Comparison of Solar Transport Vehicle with Full Electric Vehicle

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Abstract

Nowadays, the earth is facing resources limitation especially fossil fuels. It is essential to make a new study of the renewable source to sustain the demand for energy. The solar car had been recognized to become an alternative way to replace the use of fossil fuels. In this research, the definition of the solar car has been discussed. The experimental model of solar cars and the fully electric car have been designed. The experimental result was compared to evaluate the performance and efficiency of solar and electric cars. It has been realized that the solar car is a good alternative way to replace the use of fossil fuels.

Keywords: Solar, Transport, Car, Solar Energy, Solar Car

Introduction

Nowadays, the earth is facing the limits to sustain the increasing population. However, the population survey proposed the present world population will undoubtedly finish at about 2-3 times the existing statistics in the next hundred years. Natural resources such as fuel and coal are

fronting a difficult period maintain with the increasing demand. Statistics show that the numbers of vehicles are ruling the transportation sector and all these vehicles are depending on fuel. figure 1 mentioned by T.S. Portal, 2015, indicates the increase in the number of cars in the past years.

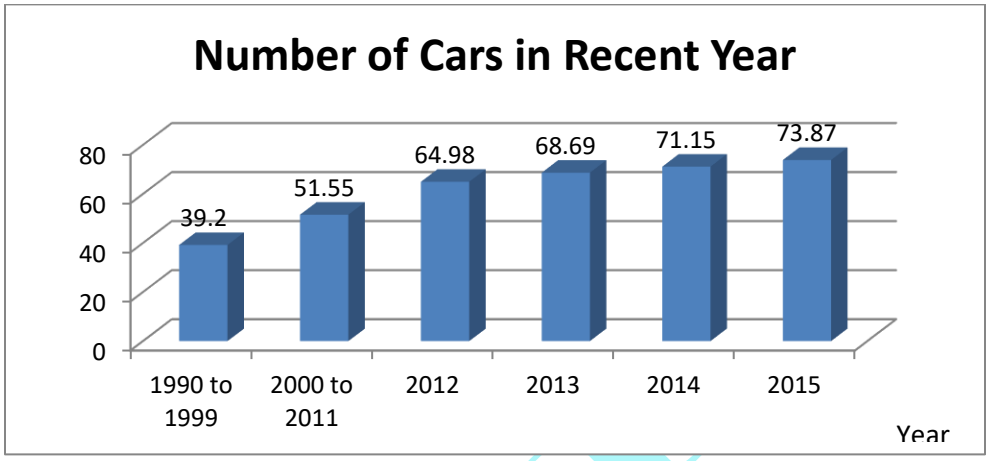

Figure 1: Number of cars in recent years

According to the result, the manufacturers and traders are suppressing the natural resources leading to scarcity of natural resources. Moreover, these resources are playing a negative role in the possibility of global warming. Consequently, it is essential to make a new study of renewable and sustainable energy to endure the population. There is a resource that is right in front of our eyes. It is effective, less cost, and an endless source of energy which is the "Solar Energy'.

Solar is a beam of energy produced by Sun. The sun emits a huge amount of energy comes from itself. The process of nuclear fusion is the hydrogen atoms combine to form helium and produce energy discussed in M. T, et al., 2010. The sun will undergo high pressure and temperature during nuclear fusion and some substances will have lost and emit into space as radiant energy. Figure 2 indicates the process of nuclear fusion discussed by M. T, et al., 2010.

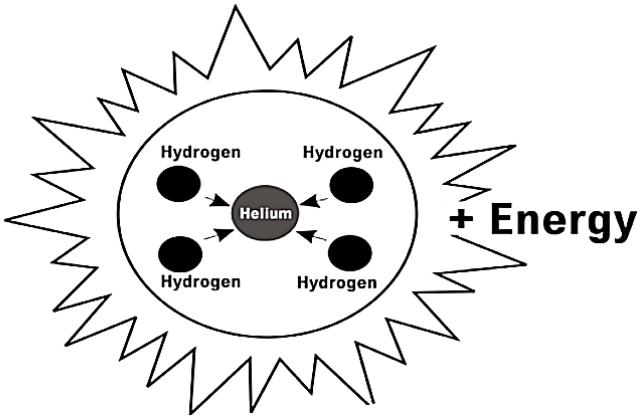

Figure 2: Process of Solar radiant

Only a minor share of the emitted energy released by the sun goes into the earth. Even with this minor share of energy, the energy is enormous and sufficient for the usage of the population. Research shows that 30% of the energy reflected in the space and 16% is used in evaporation of water which produces rainfall. Plants, land, and ocean will absorb the sunlight and the rest will go to the energy demand that the earth needs. figure 3 shows the distribution of solar energy discussed in M. T, et al., 2010.

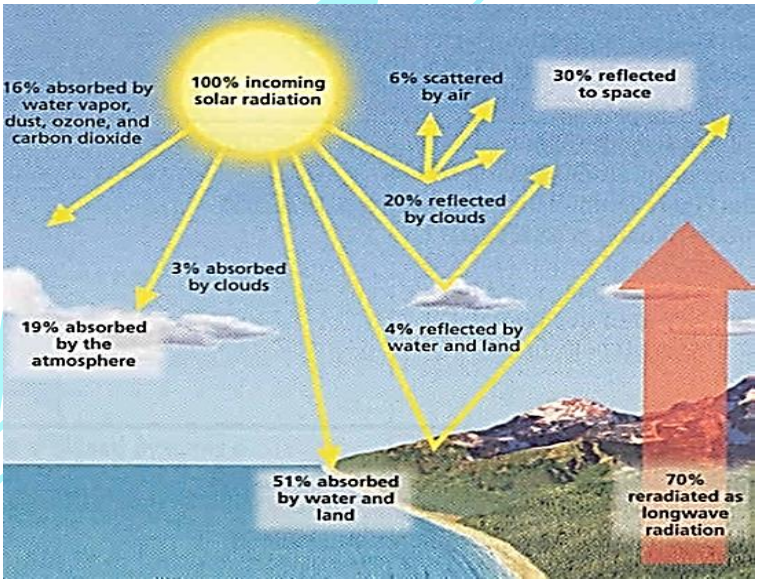

Figure 3: Distribution of Solar Radiation

Sunlight is considered the source of energy that can be implemented in daily applications. Electricity is produced using solar energy. The advance of technology nowadays had helped to aim to produce a solar energy vehicle. The objectives are to:

- To implement the idea of solar vehicle

- To study the effective & efficiency of solar vehicle
- To determine the practicability of the solar vehicle
- Through a prototype to extend the future work on building a cost-effective and environmentally friendly vehicle

Literature Review

A solar vehicle is an electric vehicle powered by sunlight through the photovoltaic (PV) cells. The PV cells convert the sunlight into electric energy to power the vehicles. However, the solar vehicles are not sold as practical day to day transportation currently but it has a promising sales in the future mentioned by E. W. Brown, 1988. Solar energy is created from heat and light sources from the sun. The energy will be captured and convert into other forms of energy. Solar cars hinge on solar photovoltaic (PV) cells to convert sunlight into electricity so that the electric motors can move. The initial concepts of solar cars are the combined technology used in bicycle and automobile businesses. In the past, solar cars are built for solar car races and then the whole concept applied to daily usage on public roads. The key component of a solar car is the solar cell. The solar cell collects the energy of the sun and directly converts to usable electrical energy which stores in the batteries of the solar car. Before that, power trackers are used to converting the energy collected from the solar array to suitable voltage so the battery and motor can use. Figure 4 shows the overview of solar vehicles discussed by M. R. F.

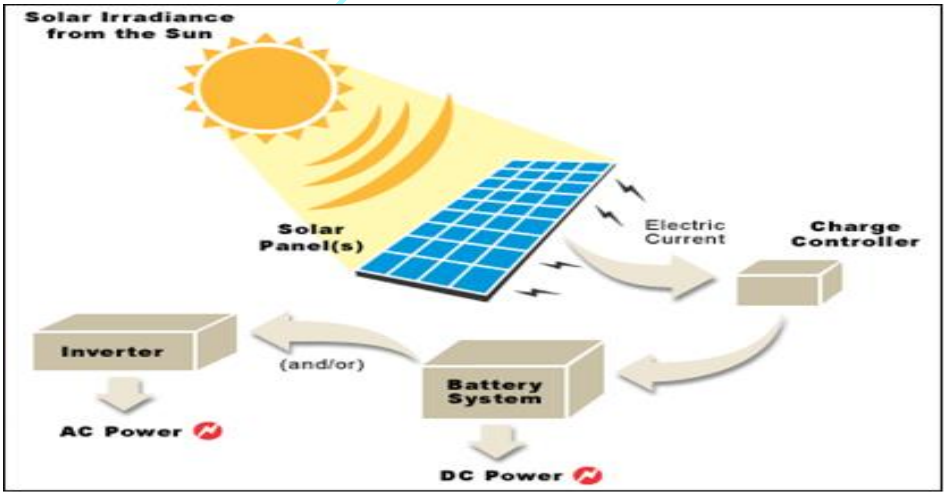

Figure 4: Basic Process of Solar Vehicle

The solar car is reflected as one of the best renewable and sustainable energy in the future. It is environmentally friendly and cost-effective. The solar cars are more practical and safer compared to electric car discussed by M. R. F.

i) Step 1- The principle

The energy used from the direct sunlight. The sunlight is directly converted into usable power needed by the car. Designed batteries in the vehicles serve as the transformer to save electricity. The most common solar accumulator is the silicon photovoltaic cells which accumulated the sunlight and move the electrons and trigger electrical current to move the vehicle.

ii) Step 2- Solar Panel

The basic appearances of the solar panels are "rectangular board" shape. It hosts the whole procedure of converting the sunlight into electricity. The size and design of the panel depending on the car make and design, whether the panels are placed on the car to allow direct sunlight.

iii) Step 3- Photovoltaic Power

Silicon photovoltaic cells are the common accumulator used to gather sunlight. The advance of technology had created batteries that can keep the electricity intact until needed.

iv) Step 4- Car Components

The car components consist of few including the solar panel, the motor-generator, batteries, power trackers, and data system to check the whole system of the car.

Advantages and Disadvantages

Table 1: Advantages and Disadvantages of Solar Vehicle discussed by Ahmed, Jubaer et. al., 2019

Advantages	Disadvantages
No Emissions Because solar-powered cars have electric motors without burning fuel and emissions. They do not contribute to air pollution and greenhouse gases environment.	Expensive PV solar cells are quite expensive. Therefore the cost of the car is high because most of the car surface is covered with a solar cell.
Preservation of Natural Resources The solar car does not require additional energy input except the solar panel because this car does not consume petrol and oil	Speed and Power Solar cars have slow acceleration as compare to a conventional car. These cars have less speed as compare conventional cars. It is better to drive a solar car for long-distance.

changes. The minimum depends on petroleum sources. the electric motor and other components are potentially maintenance free.	
No Fuel Costs These cars are considered economic in development due to less dependency on external fuel sources. They are free from fuel costs. Sunlight is converted into electricity to get the power source.	Power Storage and Consumption The solar car used sunlight to get power, so when there is less sunlight the battery ruin faster. The heavy batteries increase the weight of the car that minimizes overall car efficiency.
Driving Comfort These cars are designed with a smaller size as compare to conventional cars and run with less noise and vibrations. They offer lightweight with a fast turning and stopping mechanism.	Maintenance Most of the car surface is coated in exposed solar energy collectors, any impact to the car surface can damage the solar panels. these are expensive to replace. Rechargeable battery systems are also expensive to maintain in terms of cost.

Impact of Solar Vehicle on society, Environment, Economic

i) Social Impact

The solar vehicle will affect the employment rate.

ii) Employment

The solar-powered car industry has created job opportunities. According to the United States, the annual growth rate of solar in the US had increased by 20% created 2.3 million solar jobs worldwide mentioned by S. Dechert,2014.

Environment Impact

i) Life-Cycle Global Warming Emissions

Even though no global warming emission related to generating electricity from solar energy but there is emission related to other stages of the solar life-cycle. This life cycle includes; manufacturing, materials transportation, installation, maintenance, and withdrawing and dismantlement mentioned by S. Dechert,2014.

Economic Impact

ii) Reduce dependence on foreign oil

According to the United States, 94% of cars, trucks, ships, and planes are depending on oil. The country imported 11.7 million barrels per day to meet the daily energy needs. The country is also facing increased competition for oil from developing nations. With the development of the solar vehicle, the dependence of oil will be reduced and the economics of the nation will be more stable mentioned by C.E. Initiative, 2011.

iii) Efficiency and Consumer Savings

Solar-powered vehicles are more efficient than conventional vehicles. When these solar-powered vehicles run on batteries alone, the cost of driving significantly lower than the conventional vehicles. According to research, the fuel costs for the solar-powered vehicle are typically 2 to 3 cents a mile as compare to conventional vehicles which pay more than 12 cents for a mile mentioned by U. Decher, 2011.

Methodology and Experiment Setup

In order to compare a Solar cell car and an electric car, two prototype cars were built. The cars are built with similar materials; the difference is that one is connected to the solar cell while the other car runs on batteries. Experiment results were obtained to compare the efficiency of battery and solar cell car. The materials are list as shown in the table below.

Table 2: Tools Description

Tools Description
19mm Aluminum Bearing Roller
Hyper mini motors
2.0mm Hollow Propeller Shaft
Mini4WD G-6 Blue G-10 Yellowish Green Gear (2pcs)
Low Profile Tire/Wheel Set
Carbon Reinforcement Gear G18 & 8T
Solar cell panels

Figure 5: Prototyping of (a) Electric car and (b) Solar cell car

Two identical electrical 4-wheel drive mini racing car is used to experiment to study the efficiency and effectiveness of using solar cell or battery pack. The prototype which is the battery car is fabricated with the material brought and the car is will be powered by two AA batteries. On the other hand, the second prototype design is similar to the battery car. The only part that needed to be modified is the positive and negative terminals with external wires and soldered to the solar cell panel. At the same time, the two solar cell panels have been connected in parallel to increase the current output of the solar power.

Table 3: Energizer E91 AA batteries specifications

Classification	**Alkaline**
Chemical System	Zinc-Manganese Dioxide (Zn/MnO_2)
Designation	ANSI-15A, IEC-LR6
Nominal Voltage	1.5 volts
Nominal IR	150-300 milliohms (fresh)
Operating Temp	-18°C o 55°C (0°F to 130°F)
Typical Weight	23.0 grams (0.8 oz.)
Typical Volume	8.1 cubic centimeters (0.5 cubic inches)
Jacket	Plastic Label
Shelf Life	10 years at 21°C
Terminal	Flat Contact

Table 4: Solar cell specification

Type	**DIP Glue**
Efficiency	15%
Voltage (V)	3
Imp (A)	0.33
Cell	Polycrystalline
Voltage temperature coefficient	-(78±10) mV/k
Power temperature coefficient	-(0.5±0.05)%/k
Output power error	±5%
Current temperature coefficient	-(0.06±0.01)%/k
Size W (mm) × L (mm)	74 × 120

The power source for both cars is stated as the table above. The electrical cars run using Energizer E91 AA batteries while the solar cell panel for solar cell car is DIP Glue solar cell. Two AA batteries were connected in series to obtain the same voltage as the solar cell which is 3 V.

Results and Discussion

Table 5: Result reading between Electric car and Solar cell car

	Electric Car		**Solar Car**	
Voltage (V)	Maximum			
Speed (m/s)	Trial 1 Trial 2 Trial 3	1.23 1.23 1.25	Trial 1 Trial 2 Trial 3	1.15 1.24 1.69
Average speed (m/s)	1.24		1.36	
Distance (m)	5		5	
Time (s)	Trial 1 Trial 2 Trial 3	4:08 4:06 4:01	Trial 1 Trial 2 Trial 3	4:34 4:04 2:95
Average time (s)	4:05		3:78	
Weight (g)	134.1		129.7	

The table above shows the results for testing the electric car and solar cell car. Voltage readings on each power source were recorded using the multi-meter. Speed and time to finish one lap of 5 m distance were taken using the stopwatch. The weight for each car was a measure of the weighing machine. From the table above, electric cars have more weight than solar cell car. Electric cars weight 134.1g while solar cell cars weight 129.7g. However, the weight difference between the two cars is 4.4g which is very small. Thus, the weight would not affect the performance of the prototypes.

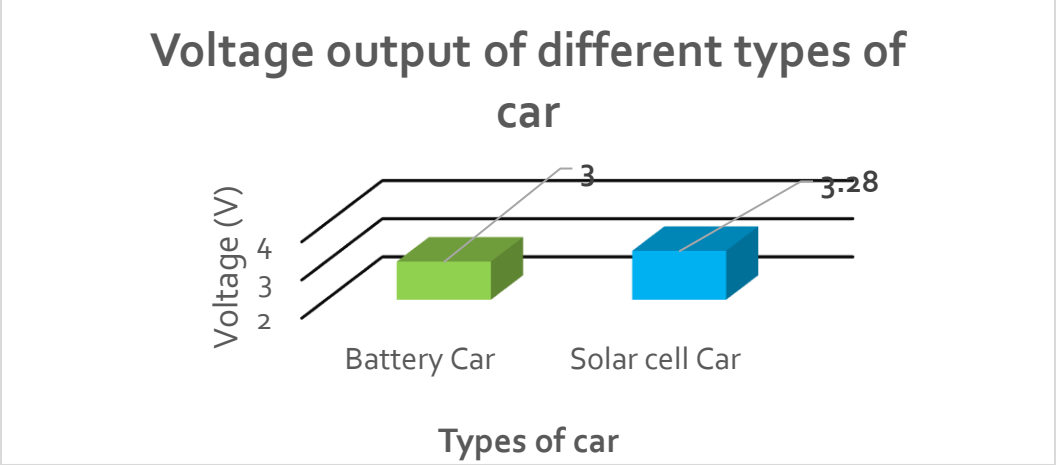

Figure 6: Graph of the Voltage output of batteries and solar cell panel

The graph above shows the voltage output of different power sources. The energy source from the electric car produced is 3 V while the solar cell car produces 3.28 V. From the result obtain, solar cell panels have higher power output than normal AA batteries.

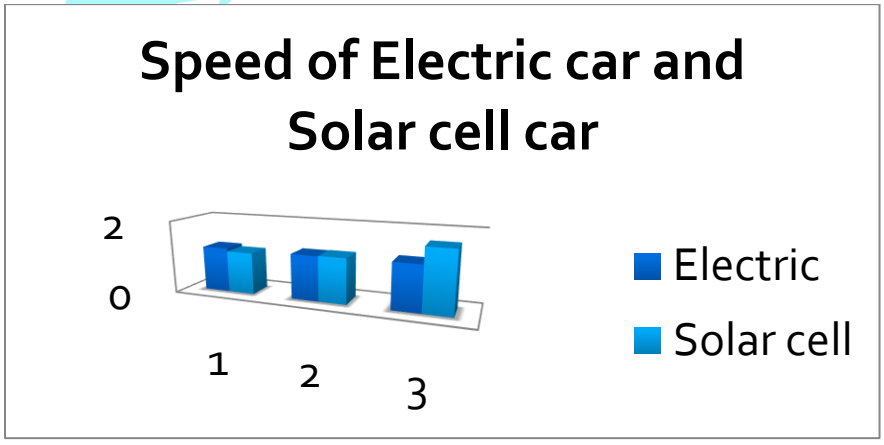

Figure 7: Speed result of Electric car and Solar cell car

The speed of the electric car and solar cell car were tabulated and plot on a graph. From the result obtained, the solar cell has various speeds. This is due to the light intensity of the sunlight during the testing. Higher light intensity will give higher speed to the solar cell car while lower light intensity will result in giving low speed. Hence, the efficiency of the solar cell car depends on the light intensity from the sunlight. For an electric car, the AA batteries will give the same amount of energy to the electric car. Thus, the electric car has almost the same speed during every testing. Although the electric car has lesser average speed compare to solar cell cars, electric cars have a constant value of speed which is more preferable to all consumers as uncertain results will affect the performance.

Table 6: Motor specification

Item No.	Motor/Spec	Voltage (V)	Torque (nM-m)	RPM (r/min)	Current (A)
15001	Hyper Mini	2.4 – 3.0	1.3 – 1.8	13000 - 15000	1.4 – 1.8

Both cars use the same motor to ensure the fairness of testing. Table 5.3 above is the motor specification.

Table 7: Costs of each car

Materials	**Cost (RM)**	
	Electric Car	Solar Cell Car
Mini 4WD	12	12
Electrical power supply	7	30
Total	19	42

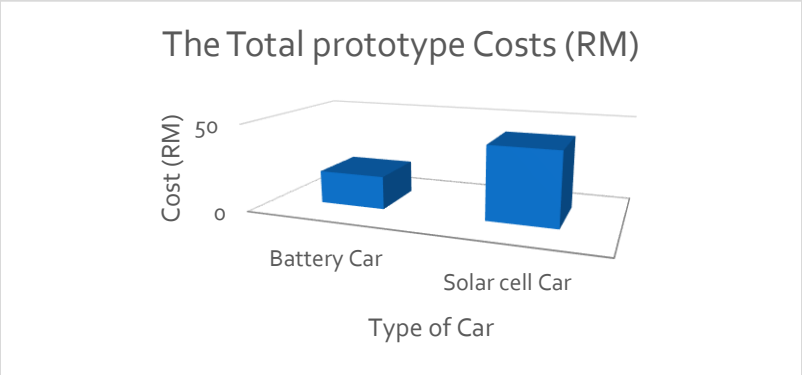

Figure 8: the total costs of the prototype

The costs for building both prototypes are shown above. The basic system on the Mini 4WD remains the same. Only the power source was modifying. The cost of building a solar car is higher compare to the electric car. This is because the solar cell is hard to build which affects the cost of it. The solar cell used in this prototyping research cost RM30 whereas two AA batteries only cost RM7. On the other hand, the solar cell can last a long time but the initial setup cost is higher on a small scale. It can be concluded that solar cars are much more expensive than the electric car. However, in the long term, using a solar cell panel will be cost-effective. The energy of AA batteries will deplete and unable to use which means the batteries are needed to be replaced. Hence, in the long term, using a solar cell panel is more cost-effective.

Challenges

During the prototyping of the models, there are many challenges to be overcome. Since the electric car for testing had been used for several runs, the potential difference of the batteries would drop throughout the testing. Hence, the result taken during the experiment may not be accurate and ideal in this case.

i) Varying solar irradiance

During the testing of the solar car, the sunlight is varying throughout the time since there are shades and clouds over time. This causes the solar irradiance collected by the solar cell is different in each testing as what is recorded in the 3rd testing of the result. Hence, we get an average of three testings for the final result.

ii) The temperature of the solar cell and battery

Both the solar cell and the battery will produce heat when being used. The effect is amplified with the broad day sunlight. Over time, when the solar cell is heated under the sun, the temperature of the solar cell will increase. This will cause the efficiency of the solar cell to drop and the output power of the solar cell will drop relatively. The same case applies to the battery pack. When the current of the battery pack is continuously supplied to the motor of the electric car, heat will be produced and reduce the efficiency of the electric car.

Recommendation and Future works

Since the prototype used the simplest systems, some additional features can be added to the system to improve the function of the solar car.

i) Power storage of the solar car

Since the solar car is not equipped with battery packs, it will only run when there is sunlight. For it to run even during insufficient sunlight, a battery pack is needed to be added into the prototype to enable the charging of the battery by the solar cell when the solar car is not in use.

ii) Increase sensitivity of solar panel in solar car

Since the solar car is run by sunlight, a system of trapping more sunlight can be made to increase its efficiency. The solar meter can be added into the system of the solar car so that it can detect the place with a huge amount of sunlight. This enables more solar energy to be absorbed by the solar systems and enhance the efficiency of the solar cell car.

iii) Adding features on the solar car

The prototype solar car can add to control systems to provide greater performance. Transmitter and receiver can be adding to enable manual control by human hands. This will increase the performance as well as the interest of people on it.

Based on the comparison between the solar car and battery car, the recommend car to be used is the solar car. From the experiment result, the solar car performed well in all the tests and the efficiency will keep increase if the intensity of sunlight is high. Also, the price for the solar car is reasonable because the solar cell is robust and has a lifespan of up to 10 years. However, in the long run, the battery car will cost more than a solar car where users need to replace a new battery pack for the car. To improve efficiency, a DC-DC converter model for the specific car can be added between the connection of solar cells to the motor to increase the current flow and get rid of the excessive voltage supply.

Conclusion

Lastly, solar technology is the future renewable energy that can be commercialized to replace other non-renewable energy such as fuel. Solar technology has been implemented for applications such as the solar heater, solar charger, solar recycling compactor, and many more. Moreover, solar technology can save the environment as air commission from other resources can be replaced by solar technology to produce electricity.

This research on solar energy car was able to achieve the new potential of solar energy application. However, the criteria for developing solar technology are the weather, environment factor, and the type of solar module. Therefore, there are still spaces for improvement in solar technology to increase performance. Based on the gathering of data and result testing for the solar car, it is found that the shortest time performance of the solar car can achieve was 2.95 second with 5 meters of distance. The calculated best speed was 1.7m/s which is almost the average speed of the human walking speed. The best solar cell voltage is 3.28V instead of 3.0V.

In conclusion, it can be seen that the differences do exist between a battery car and a solar car. This research can provide a solution to energy-saving and achieve energy-efficient design guidelines and incentives. Overall, all the objective set of the research is accomplished. Thus, solar energy should be wisely used to enhance sustainability.

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