

# Feasibility analysis of solar electric vehicles

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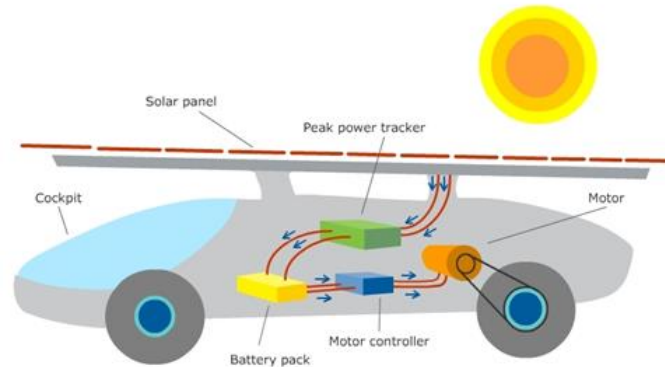
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**Abstract.** Solar-powered cars offer a compelling solution to the challenges of conventional transportation, utilizing solar cells to convert sunlight into clean and renewable energy for propulsion. This paper explores the principles, advantages, and challenges of solar cars while examining their evolving landscape in the automotive industry. Solar cars are celebrated for their environmental benefits, offering true zero carbon dioxide emissions, resource conservation, and minimal maintenance. Moreover, they significantly contribute to noise reduction, offering a quieter driving experience. Despite these advantages, solar cars face challenges that hinder their widespread adoption. Weighty solar panels limit driving range, and energy production often falls short of consumption during operation. Charging infrastructure remains a concern, especially in comparison to the convenience of refueling traditional vehicles. However, innovations such as the Lightyear One prototype demonstrate the potential for long-range solar-powered vehicles, while the feasibility of solar hybrid cars is a subject of ongoing discussion. Continuous advancements in solar cell technology, particularly silicon-based cells, hold promise for improving efficiency and cost-effectiveness. Conclusively, solar-powered cars represent a sustainable and environmentally conscious future for transportation. With research, technological innovation, and global collaboration, solar vehicles have the potential to transition from promising prototypes to practical and accessible alternatives, contributing to a cleaner and greener planet.

**Keywords:** Solar-Powered Electric Vehicles, Solar Panels, Solar Technology.

## 1. Introduction

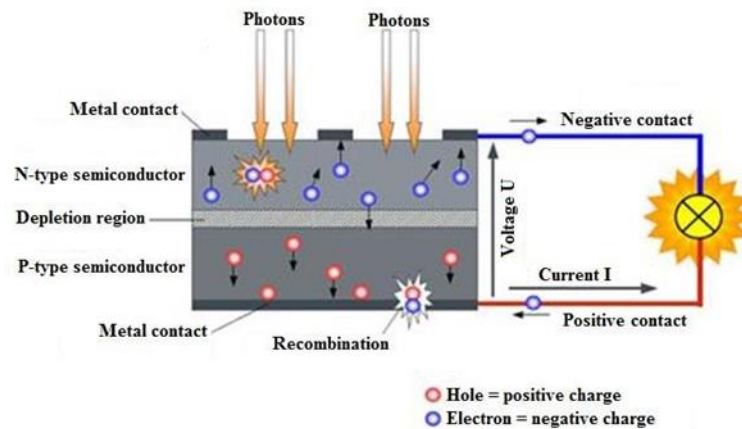
Solar cars utilize solar cells to convert light energy into electricity, which is stored in a battery to power the vehicle's motor (Figure 1) [1]. These vehicles, which run on clean, inexhaustible solar energy, are emissions-free and have garnered widespread interest in environmentally friendly transportation [2]. Many countries advocate for solar vehicles, leading to a booming solar car industry. However, practical implementation has been hindered primarily by high costs and limited mileage [3]. Various nations host solar car races, fostering collaboration among researchers, educational institutions, and automotive companies, resulting in remarkable technological advancements over the past two decades, including high-speed, aerodynamic models. Nevertheless, the recent World Solar Challenge in Australia revealed the significant cost barrier, with some solar cars exceeding USD 1 million in price. To make solar cars economically viable for mass production and everyday use, researchers must prioritize the development of cost-effective and reliable options.



**Figure 1.** Diagram of solar energy-powered electric vehicles [4].

## 2. Working Principles of Solar Energy-Powered Cars

Solar cells are devices that directly convert sunlight into electrical energy through photoelectric or photochemical processes. When sunlight interacts with a semiconductor, some of it bounces off the surface while the rest gets absorbed or passes through the semiconductor. Some of the absorbed light turns into heat, while others create electron-hole pairs when photons collide with the atomic valence electrons within the semiconductor. This conversion process results in the generation of electricity in the form of these electron-hole pairs [5] (Figure 2).



**Figure 2.** Working principle of the solar panel [6].

Currently, the predominant type of solar cells used is silicon-based solar cells, which are comprised of large-area PN junctions made from silicon semiconductor materials connected in series and parallel. An N-type material layer typically has a metal grid wire as a contact electrode, and a metal film on the back acts as another contact electrode, forming a solar panel [7]. To minimize light loss, an anti-reflection film is often applied to the surface. Common types of silicon solar cells include monocrystalline, polycrystalline, and amorphous silicon cells. Solar cells are typically integrated into solar panels and are an integral part of a solar photovoltaic power generation system. These panels convert solar energy into electricity, with monocrystalline or polycrystalline silicon panels being the most commonly used due to their high photoelectric conversion efficiency and long service life, often reaching up to 20 years [8].

In a solar power system, solar cells are typically used in conjunction with photovoltaic controllers and batteries to create a complete solar power source. The photovoltaic controller's primary role is to safeguard the battery by providing overcharge and over-discharge protection, controlling power output, offering charging trickle protection, implementing temperature compensation, and providing lightning

protection, among other functions. When the solar panel charges the battery, if the battery voltage reaches its peak and continues to charge at a high voltage, it can potentially harm the battery. To prevent this, the controller promptly reduces the voltage after reaching the peak, entering a trickle charging phase to maintain the battery in a fully charged state, thus extending its lifespan. This ensures effective protection for the battery, enabling it to last longer. The fundamental principle underlying this process is known as the photovoltaic effect, where light hitting the semiconductor PN junction generates an electromotive force at both ends, resulting in the generation of electricity [9]. This phenomenon is referred to as the photovoltaic effect of the PN junction, driven by the built-in electric field in the depletion region of the PN junction.

### **3. Advantages of Solar Energy-Powered Cars**

Solar-powered cars offer several compelling advantages compared to conventional pure electric vehicles. While pure electric cars do not produce tailpipe emissions, their limited driving range necessitates frequent charging, often powered by fossil fuels, leading to increased carbon dioxide emissions from power plants. In contrast, solar-powered cars have the potential to achieve true zero carbon dioxide emissions since they harness energy directly from the sun. This addresses the environmental issues associated with global warming and eliminates the reliance on fossil fuels for electricity generation. Solar energy is a rapidly growing and abundant resource that, if harnessed for automotive use, could significantly reduce carbon emissions and mitigate the negative environmental impacts of traditional electric cars [10].

Another major advantage of solar-powered cars lies in their resource-saving and pollution-reducing capabilities. By substituting oil with light and electricity as their energy source, solar cars contribute to the conservation of limited oil resources. These vehicles also operate with zero emissions and produce no harmful pollutants, leading to substantial reductions in carbon dioxide emissions, estimated at 43 to 54% compared to traditional fuel vehicles. Additionally, solar cars are remarkably quiet due to the absence of internal combustion engines, minimizing noise pollution. Furthermore, these vehicles require minimal daily maintenance, eliminating the need for frequent oil changes and other traditional car upkeep, resulting in lower maintenance costs. These combined advantages make solar-powered cars a promising and sustainable alternative for environmentally conscious transportation [11].

Solar energy is abundant and widely distributed, which means that solar-powered cars can tap into this readily available resource almost anywhere in the world. Moreover, as solar technology continues to advance, improvements in energy conversion efficiency and energy storage capabilities may overcome some of the current limitations, such as limited driving range. This paves the way for a future where solar-powered cars become a viable and practical choice for everyday transportation, contributing to a cleaner and more sustainable environment while reducing the reliance on finite and polluting energy sources.

### **4. Challenges of Solar Energy-Powered Cars**

Solar-powered cars have made remarkable strides in recent decades, symbolized by events like the World Solar Challenge and advancements in various aspects of their design. Originating from the pioneering 1982 journey across Australia, solar vehicles have evolved into impressive machines with higher energy efficiency and speed. For instance, the 2009 winning solar car from Tokai University in Japan achieved an average speed of 105 km/h, showcasing significant progress in solar car development. [12]. However, these advancements are not without challenges. Solar panels, typically sized at 8-12 square meters, can weigh around 100-150 kg due to their weight of 12-14 kg per square meter. This substantial weight affects the car's range and speed. For example, the "Tianjin" solar car boasts a cruising range of 74.8 km, and even in full sunshine, it can only reach 79.2 km, illustrating the limitations imposed by solar panel weight.

Another crucial challenge is the limited energy production of solar panels compared to the energy consumption during driving. The Sonata Hybrid car, for instance, can only charge 30%-60% of its 1.76 kWh battery over six hours using its solar panels. This highlights the need for more efficient solar panels

to harness sufficient energy from the sun and overcome the shortfall in energy required for driving. Moreover, electric vehicle charging times typically range from 2 to 9 hours, posing convenience challenges for users, especially when compared to the relatively quick refueling of conventional vehicles. To make solar cars more practical for everyday use, improvements in solar panel efficiency and charging infrastructure are crucial.

Despite these challenges, ongoing developments and innovative solutions continue to drive the solar car industry forward. Organizations like the World Solar Challenge are actively introducing regulations that push for more "normal-car-like" features in solar cars, including indicators, reverse gears, and better accessibility. As technology advances and regulations adapt, solar cars may ultimately become more user-friendly and competitive with traditional vehicles, contributing to a sustainable and eco-friendly future in transportation.

## **5. Current Status and Application of Solar Energy-Powered Cars**

### *5.1. The Lightyear One Prototype*

The Lightyear One prototype showcases a cutting-edge solar car design, featuring sleek black solar panels covering the hood and roof, spanning an area of 54 square feet. These solar panels continuously charge the car's battery as long as there is sunlight available. The vehicle's driving range is subject to climate conditions and driving frequency, with optimal performance achieved in consistently sunny locations. In ideal circumstances with uninterrupted sunlight, the Lightyear One can travel up to 12,000 miles annually using solar energy alone. Even when parked in shaded or indoor areas, it can cover approximately 8,300 miles per year, while in regions with cloudier weather like the Netherlands, it can still manage around 4,375 miles per year. Additionally, the car can be charged via a traditional power supply when necessary [13].

The journey of Lightyear One originated from the renowned Bridgestone World Solar Challenge, initiated in 1987 and conducted biennially. This competition tasks engineers with constructing a car capable of traversing 1,875 miles solely on solar energy. The Lightyear team evolved from students at the University of Eindhoven, who meticulously refined their solar car design, known as Stella, with guidance from faculty in the Department of Electrical and Mechanical Engineering. Stella competed in the "cruiser group" of the World Solar Car Challenge, accommodating three passengers throughout the race. It maintained an average speed of 41.6 miles per hour and reached a peak speed of 74.6 miles per hour, completing the race in 40 hours and 14 minutes. This prototype experience laid the foundation for the innovative Lightyear One solar car [1].

### *5.2. The Feasibility of Solar Hybrid Vehicles*

The feasibility of solar hybrid cars represents a complex interplay of various factors. While the idea of harnessing solar energy to power vehicles is alluring due to its environmental benefits and potential for energy savings, practical challenges persist. Integrating photovoltaic systems with hybrid and electric vehicles adds weight and cost to an already intricate system. This extra weight can impact the vehicle's efficiency and battery life, potentially offsetting the advantages of solar power. Moreover, the effectiveness of solar panels is highly dependent on factors like sunlight availability and driving patterns. In intermittent use with average power demands, solar hybrid cars may offer fuel savings and economic viability, particularly in urban driving scenarios. However, achieving widespread feasibility requires addressing technical challenges such as weight reduction, battery optimization, and cost-efficiency. Furthermore, advancements in solar panel technology, coupled with improvements in vehicle design and energy storage, are necessary to make solar hybrid cars a more practical and environmentally friendly choice for everyday use [14].

### *5.3. The Current Research Status of Solar Cells*

Solar cells are currently the main means of converting solar energy to use, and Bell Labs in the United States has successfully developed the world's first solar cell, but the cost is expensive and the cell

efficiency is low. Nevertheless, people have begun to widely invest in the research of large solar energy cells, and solar cells are also constantly improving and maturing. According to the different materials, solar cells can be divided into silicon solar cells, inorganic salt solar cells, etc. Among these solar cells, silicon-based solar cell technology is the most mature, applicable and high light energy conversion efficiency, dominant [15]. Conversion efficiency is the most critical performance index of solar energy cells in China. Compared to other solar cells, silicon solar cells have the highest conversion efficiency, especially since the twentieth century. The cost of solar cells is getting lower and lower, the conversion efficiency is getting higher and higher, and its output has also shown explosive growth. However, the energy conversion efficiency of solar panels has not increased significantly, resulting in difficulties in the development of solar vehicles.

## 6. Conclusion

In conclusion, solar-powered cars represent a promising and environmentally friendly solution for the future of transportation. These vehicles harness the abundant energy of the sun to provide clean, emissions-free mobility. While the concept of solar cars has been met with enthusiasm and has seen remarkable technological advancements, challenges remain on the path to their widespread adoption. The development of solar cars has been significantly driven by events like the World Solar Challenge, where teams from around the world compete to push the boundaries of solar vehicle technology. These competitions have led to innovations in aerodynamics, lightweight materials, and energy management systems, resulting in faster and more efficient solar cars. However, the substantial cost associated with advanced technologies has been a significant hurdle to mass production and commercial viability. Solar cars offer numerous advantages, including the potential for true zero carbon dioxide emissions, resource conservation, noise reduction, and minimal maintenance. Their reliance on an abundant and renewable energy source positions them as a sustainable alternative to traditional vehicles. However, challenges such as limited driving range due to solar panel weight, energy production versus consumption, and charging infrastructure need to be addressed for solar cars to become more practical for everyday use. The accomplishment of the prototype exemplifies the progress made in solar car development, showcasing the potential for long-range solar-powered vehicles. While solar hybrid cars present intriguing possibilities, they face technical hurdles, including weight and cost considerations. The continuous advancement of solar cell technology, particularly silicon-based cells, holds promise for improving the efficiency and cost-effectiveness of solar vehicles.

In conclusion, the journey toward practical and economical solar cars is ongoing. With ongoing research, technological innovation, and the commitment of the global scientific and automotive communities, solar-powered cars have the potential to become a sustainable and accessible mode of transportation, contributing to a cleaner and greener future for the planet.

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