World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

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Comparison of solar cells and efficiency initiatives

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World Journal of Advanced Engineering Technology and Sciences, 2025, 14(01), 211-218

Publication history: Received on 17 December 2024; revised on 25 January 2025; accepted on 28 January 2025

Article DOI: https://doi.org/10.30574/wjaets.2025.14.1.0026

Abstract

We investigate the benefits of photovoltaic and photovoltaic systems-based research to find more ways to meet global energy and climate reform benchmarks. Similarities in panel construction can be used with market data to create jobs, increase throughput efficiency, and save space. Developers can forecast the market and create predictions for future investments in stable development when they consider the most recent research efforts. To enhance the existing research efforts, we also show simulation results of various solar cells using different materials which can guide us to choose correct materials in construction of solar panels.

Keywords: Solar cells; Energy; Material; Panel

1. Introduction

Since the 1950s, there has been a notable increase in the use of solar cells. The world's first leader in solar photovoltaic electricity generation was the United States, which was followed by Germany, Japan, and now China. Between 1992 and 2022, photovoltaics' global expansion accelerated, moving from a small-scale application niche to a widely used electricity source [1]. Japan and European nations that pioneered Critical Research Allocations (CRA) were the primary drivers of this growth. Investments in research have been essential to the advancement of solar cells. For example, a study team demonstrated a power conversion efficiency of 23.6%, which is comparable to that of traditional silicon solar cells, setting a record for solar cells built with perovskite and organic materials [2]. According to Current Development Plans (CDP), experimenting with placement and arrangement will boost efficiency. Longer-lasting solar cells, solar cells that can be printed onto flexible surfaces, solar panels that follow the sun's path from east to west during the day, and nighttime solar power plants are among the current development goals in the solar cell sector. However, some of these choices point to solutions that call for further systems, which could present their own difficulties. Variability in the market is determined by centralized manufacturing (CM). The solar cell business relies heavily on centralized manufacturing. In just three Southeast Asian nations—Vietnam, Malaysia, and Thailand—Chinese subsidiaries produce over 75% of the silicon solar cells deployed in the US. Low conflict material at lost cost is provided by Material and Product Sourcing (MPS) [3].

Most of the raw materials used to construct solar panels are silicon-based components, which are found in abundance in earth minerals and are essential for the creation of electricity-producing cells. This semiconducting material is preferred because it can be doped in purity purging, making it available for both positive and negative junctions. The municipal government offers Manufacturing Rebates & Incentives (MRI). Numerous solar incentives and rebates are provided by local governments. The city of Fort Collins, Colorado, for instance, provides a $250 municipal incentive for each kW of installed solar up to $1,000. State governments provide incentives as well. In addition to the federal solar tax credit, there are solar tax credits available in several states. For instance, New York State offers a solar tax credit of 25% up to $5,000.

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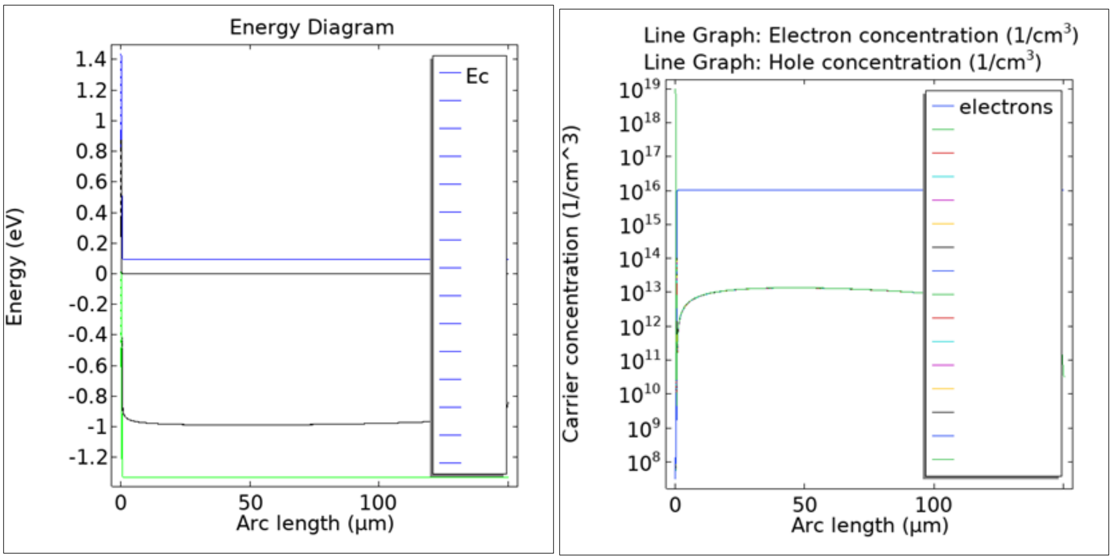

Figure 1 Energy diagram of GaAs solar cell and carrier concentration of GaAs solar cell

Federal Agencies and implemented programs. The federal clean energy tax credit, which reimburses up to 30% of the cost of installing solar panels to the taxpayer in the year following installation, is the most significant solar incentive at the federal level [4]. What to look for in Key Performance Indicators (KPI). Total revenue, cost per kWh, cost of individual solar panels, gross profit margin, labor efficiency, inventory turnover ratio, rate of solar panel installation, and specific yield are all examples of key performance indicators (KPls) for solar panels.

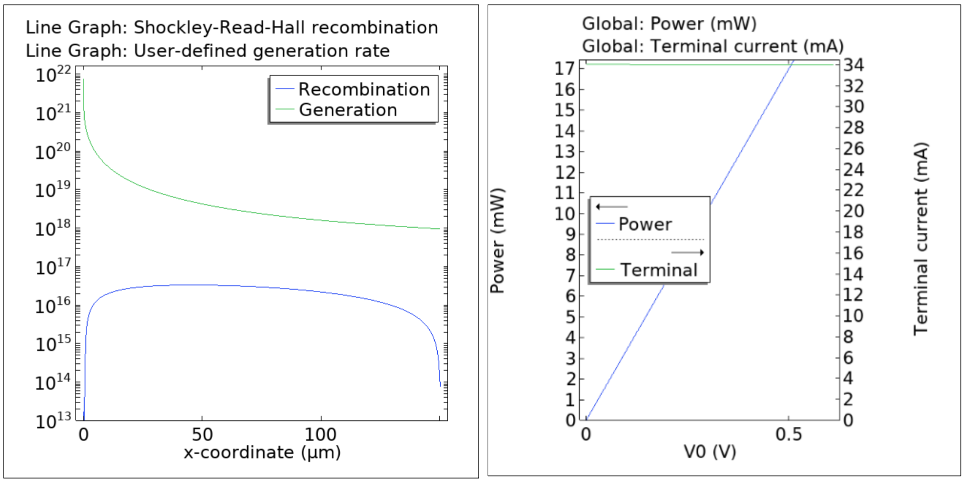

Figure 2 Recombination rate of GaAs solar cell and I-V graph of GaAs solar cell

Potential Late Adopters and Channel Relatedness. In the market for solar cells, late adopters still have a lot of promise. According to a Pew Research Center survey conducted in January, 39% of American households have seriously considered installing solar panels in the past year, and 8% of homeowners have already done so [5]. This suggests a significant unexplored market for the use of solar cells. The interdependence of several elements impacting the adoption of solar cells, such as market dynamics, governmental regulations, and technological developments, is referred to as the relatedness of channels. Microgrids and Resilient Emergency Management. Microgrids, which are decentralized electric power systems that use locally generated natural gas and solar energy, have been developed and implemented in Japan by pioneers. In Japan, these microgrids have played a significant role in strengthening local communities' resilience. An excellent illustration of this is the Mutsuzawa Smart Wellness Town in Chiba [6]. Prefecture, which has set up a microgrid of locally run power lines and a cogeneration system utilizing locally produced natural gas.

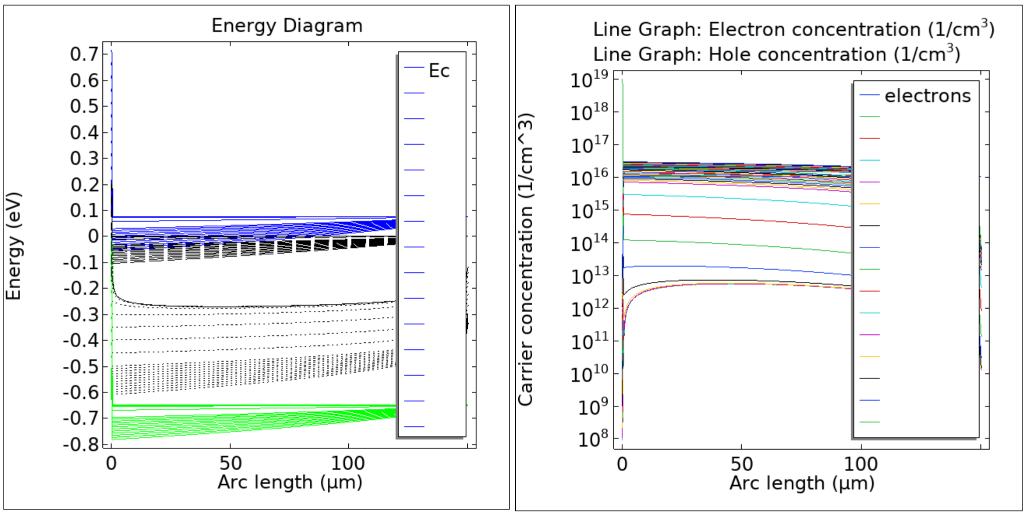

Figure 3 Energy diagram of GaSb solar cell and carrier concentration of GaSb solar cell

This municipality uses solar energy and locally extracted natural gas to generate half of its electricity, which is then distributed via its own power lines. But not every Japanese city has implemented microgrids. For example, Higashi Matsushima chose to use microgrids and decentralized electricity to restore its energy infrastructure following the 2011 Tohoku disaster. The city's dependence on macro-scale power networks led to widespread power outages, which prompted this decision [7].

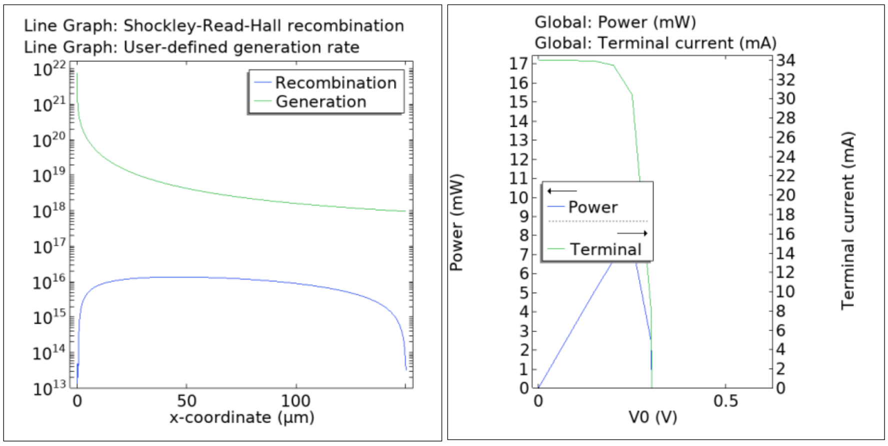

Figure 4 Recombination rate of GaSb solar cell and I-V graph of GaSb solar cell

Germany has taken the initiative to encourage the growth of wind and solar energy. The government has enacted new laws that facilitate towns' involvement in already-existing wind and solar parks and identify new locations for PV development. A range of feed-in tariffs (FITs) for solar PV projects of different sizes make up the nation's solar PV program [8]. For 20 years, these FITs have provided a set payment for power generated by solar PV facilities. Consequently, the number of solar PV installations has skyrocketed, with a total installed capacity exceeding 35 gigawatts by the end of 2013 [9].

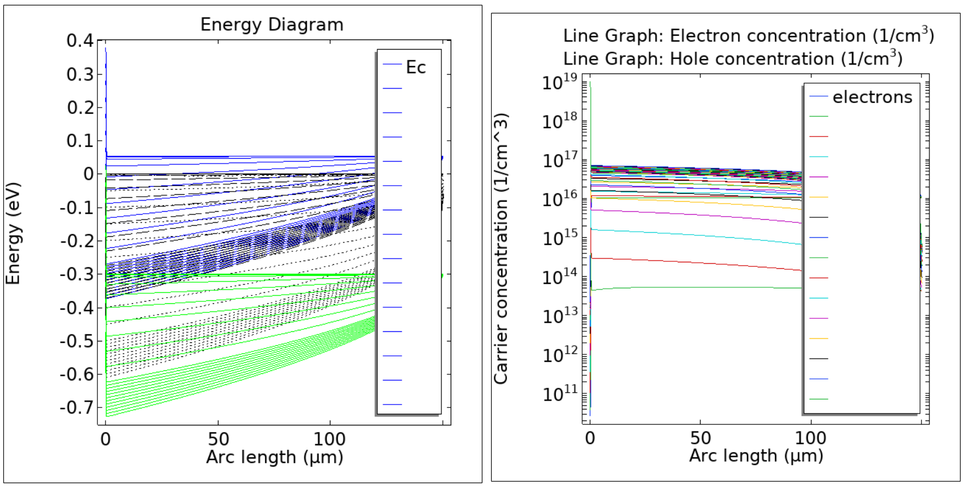

Figure 5 Energy diagram of InAs solar cell and carrier concentration of InAs solar cell

Mexico's solar power efficiency. Mexico has advanced significantly in its use of solar energy. 26.7% of Mexico's electricity, or 86.27 Tera-Watt hours, came from clean energy sources in 2021. The size of the nation's solar photovoltaic market is anticipated to increase at a compound annual growth rate (CAGR) of 8.91% from 9,800 megawatts in 2023 to 15,016.37 megawatts by 2028 [10].[11]. Manufacturing of solar panels in China and Mexico. With an expenditure of $20 million, Mexico has begun manufacturing at its plant in Tecoman, in the state of Colima [12].

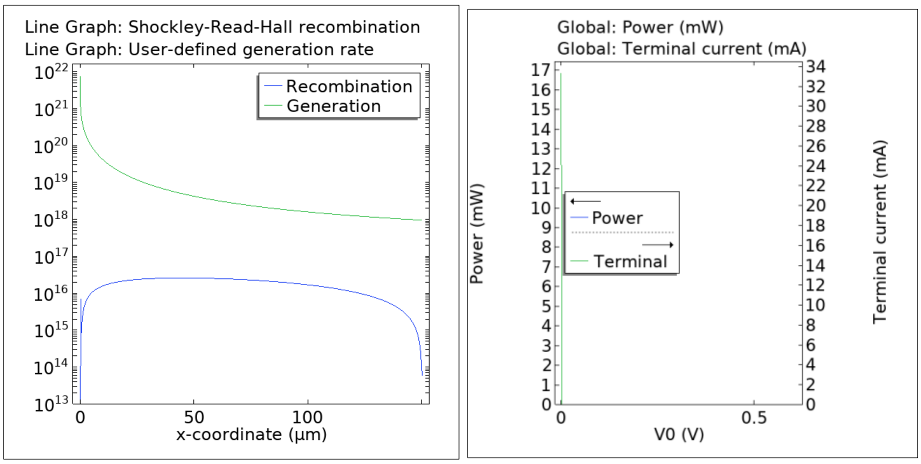

Figure 6 Recombination rate of InAs solar cell and I-V graph of InAs solar cell

The first of the factory's three production lines, which can produce 500 Mega Watts annually, is currently in use [12]. However, because polysilicon costs have lately dropped, the cost of producing a solar panel in China has also decreased. In China, mono perc is currently sold at about USD 0.196 per watt peak (wp) Free on Board (FOB) [13]. Solar panel market stakes in China and Mexico. With more than 80% of the solar panel manufacturing process, China controls most the world's solar PV supply chains. The market for solar photovoltaics in Mexico, on the other hand, is fragmented, with leading producers including Enel SpA, Engie SA, Canadian Solar Inc., Risen Energy Co. Ltd., and Hanwha Q Cells Co. Ltd. International regulations as well as sourcing panels. Independent countries must be mindful of international orders, sanctions, taxes, embargoes, and red tape while purchasing solar panels from China and Mexico. For example, the United States has levied a 25 percent duty on solar panels that are made in China or that use solar cells as their primary component.

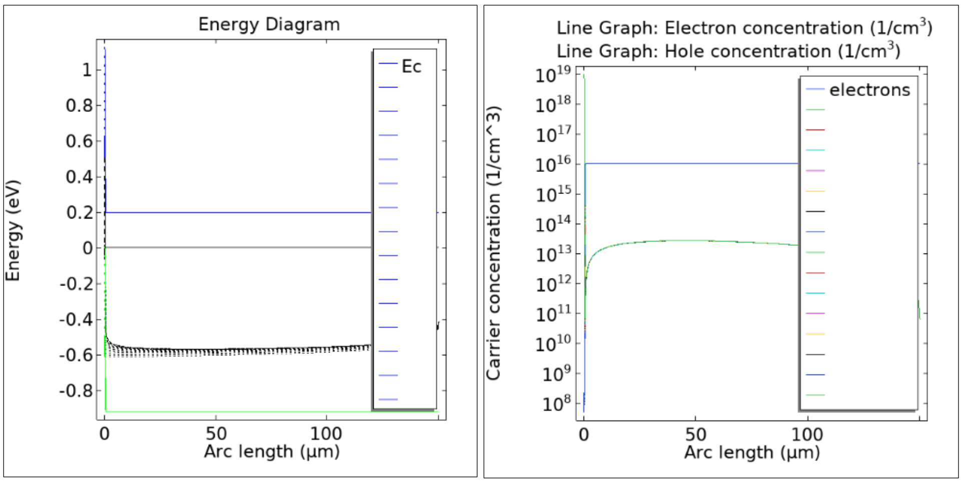

Figure 7 Energy diagram of InP solar cell and carrier concentration of InP solar cell

Aside from that, the U.S. Department of Commerce also revealed its initial findings in the investigations into solar cells and modules from the PRC that may result in further tariffs [14] [15]. Consequently, while procuring solar panels from these nations, countries must take these variables into account.

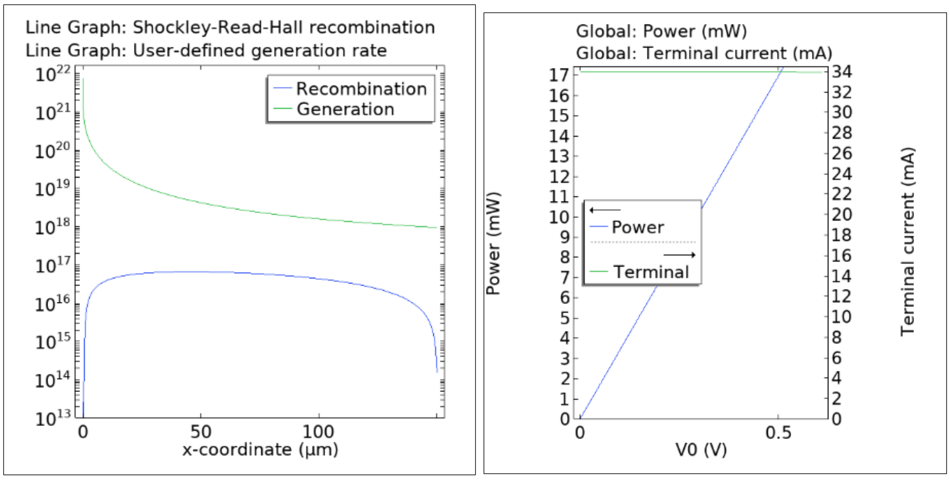

Figure 8 Recombination rate of InP solar cell and I-V graph of InP solar cell

Allocating funds for research has been essential to the advancement of the solar energy sector. Because of the notable technological, economic, and efficiency improvements they have brought about, solar energy is now a competitive and sustainable substitute for conventional energy sources. The top three evidence-based remedies that have had a major influence are as follows: Decentralized and Off-Grid Solar: The main goal of this approach is to supply solar energy to isolated locations without access to the conventional electrical grid. It has given millions of people throughout the world access to energy solutions and opened new markets. Grid-connected and utility-scale Solar: This option entails setting up massive solar farms that supply power straight to the grid. It has greatly expanded solar energy generation's total capacity. Advanced Solar and Storage Technologies: This approach entails creating new solar energy storage technologies, like sophisticated batteries. It has addressed the sporadic nature of solar energy, one of the main issues facing the solar industry. Efficiency Increases Over Time. Over time, solar panel efficiency has significantly increased. Hoffman Electric produced photovoltaic (PV) cells with an efficiency of 14% in 1960.

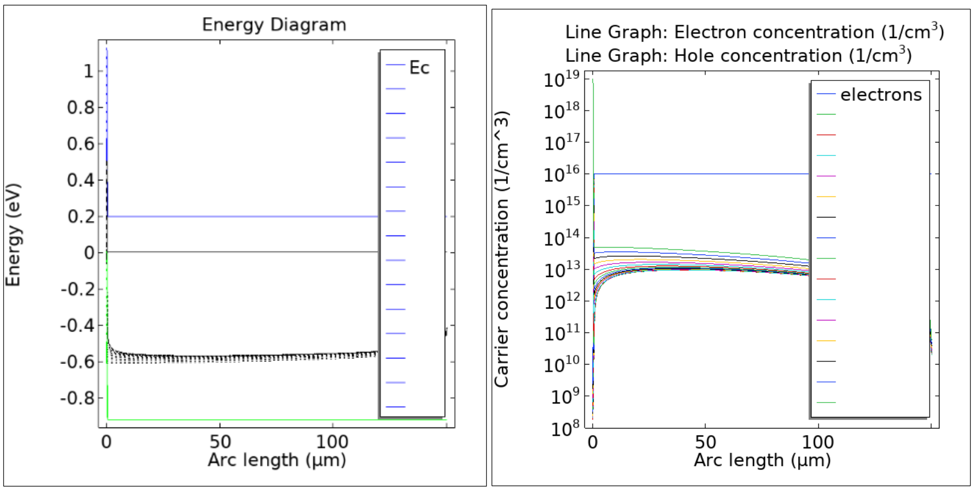

Figure 9 Energy diagram of Si solar cell and carrier concentration of Si solar cell

2. Procedure

Numerous technologies and materials have been studied to help develop electronics that may find use in solar panel applications [16–29]. One advanced technique for figuring out the ideal particle sizes and arrangements in a hexagonal array construction is the finite-difference time-domain (FDTD) method. Maxwell's equations can be solved numerically using FDTD. Four equations known as Maxwell's equations explain how electromagnetic waves behave. The way FDTD operates is by creating a grid of tiny cells throughout the area. Each grid cell's electric and magnetic fields are then computed over time. Another prominent method uses finite element method and COMSOL software is based on this method. Solar cell simulation results using various materials using COMSOL software are shown in Figure 1 to Figure 10.

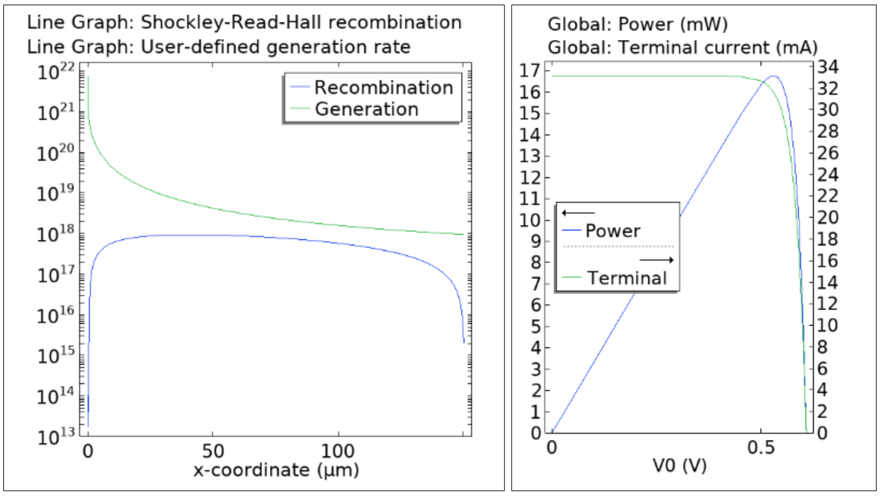

Figure 10 Recombination rate of Si solar cell and I-V graph of Si solar cell

3. Conclusion

Customers' decisions to use solar panels are directly impacted by the manner the panels are arranged, which alters quality characteristics. Initiatives to increase power output and capacity, financial initiatives to support the new electric ecosystem, and a strong emphasis on performance with quality are all in place. Consumer-used panels have an average lifespan of 25 years and an efficiency of 18%. It is theoretically possible to improve power generation by taking 25% of solar owners who have solar panels having less efficiency and encouraging them to use panels that produce higher efficiency. This is essential to achieving the objectives set by the international community.

Compliance with ethical standards

Acknowledgments

This work was supported as part of the Modeling and Simulation Program (MSP) grant funded by the US Department of Education under Award No. P116S210002 and Improving Access to Cyber Security Education for Underrepresented Minorities funded by the US Department of Education under Award No. P116Z230007.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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