INCREASING THE EFFICIENCY OF SOLAR PANELS

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Abstract. This article is dedicated to enhancing the efficiency of solar panels through technological solutions. The study aims to showcase technological solutions that improve the efficiency of solar panels. General scientific methods of cognition such as analysis, synthesis, comparison, and generalization were employed during the research. The results indicate that several technological solutions in modern solar energy significantly increase the efficiency of solar panels. These include the use of additional mirrors, Fresnel lenses, spherical concentrators, optimal positioning of solar panels, trackers, high-temperature materials, as well as modular and hybrid solar systems. Innovations in this field encompass improvements in panel efficiency, expanded use of bifacial panels, integration of photovoltaics into building materials, energy storage solutions, and the proliferation of "smart" solar systems, promising a revolution in renewable energy sources. Recent innovations in solar energy herald significant changes in the renewable energy sector, particularly due to advances in photovoltaic technologies. Key trends include increasing the efficiency of solar panels, implementing bifacial panels that collect light from both sides, integrating photovoltaics into building materials, the rise of energy storage solutions, and the spread of "smart" solar systems. Innovative solutions include Mega Sunergy's overlapping photo cells, which increase panel efficiency by 5-17%, the use of perovskite solar panels with over 25% efficiency, transparent solar panels for integration into windows and building facades, floating solar farms that conserve land resources and enhance efficiency through water cooling, solar skins for aesthetic panel appeal, and AI-based energy optimization systems that boost performance by analyzing and adjusting system operations. Future solar energy development technologies in the coming years anticipate a reduction in the cost of solar panels and an increase in their innovative potential. The active implementation of solar energy in various sectors of the national economy, including logistics, will be a key direction. The practical significance of the study lies in identifying key technological solutions that contribute to improving the efficiency of solar panels and the development of renewable energy sources.

Keywords: efficiency, solar panels, technologies, innovations, renewable energy sources.

Introduction

The efficiency of solar energy is determined by technological characteristics that affect the ability of solar panels to convert sunlight into electrical energy. Key indicators include the efficiency (coefficient of performance) of the panels, the durability of materials against climatic conditions, and the longevity of the structures. The use of high-temperature materials, optimal panel placement, trackers, and other technologies significantly enhance the overall performance of solar systems. Increasing investments in the solar energy sector drive manufacturers to create and implement new technologies. Key innovative solutions already in use or under active development include additional mirrors, Fresnel lenses, spherical concentrators, trackers, high-temperature materials, modular and hybrid solar systems, Mega Sunergy's overlapping photo cells, perovskite solar panels, transparent solar panels, floating solar farms, solar skins, and AI-based energy optimization systems. These technologies help increase the efficiency of solar panels, making them more accessible and productive.

Different technologies are used for various purposes, allowing for the creation of an energy-independent and energy-efficient state with accessible energy for the population. Integrating solar panels into building materials, using transparent solar panels for urban conditions, and implementing floating solar farms help efficiently utilize available resources. Government and legislative support aimed at developing renewable energy sources plays a crucial role in creating a stable and environmentally clean energy future.

Literature review

The issue of increasing the efficiency of solar panels is well-studied in foreign scientific literature. Significant contributions to the topic's development have been made by authors such as T. Özer and Ö. Türkmen [10], who developed a low-cost solar panel detection system using drones and artificial intelligence. V. R. Akshay [1] in his forecast for the future of solar energy highlights significant technological innovations expected in 2024 and beyond. A. Priyam [11] conducted a review of solar tracking systems that enhance the performance of solar panels. He examines various types of trackers and their impact on system efficiency, emphasizing the importance of technological solutions for optimizing solar energy use [11]. The study also utilized expert literature, including publications in modern online media that cover contemporary aspects of the topic. For instance, an article on the Republic of Solar website [1] and publications by Defend Solar USA Alliance [5] provide important information on the current state and development prospects of solar energy in the context of global trends and challenges.

Despite the sufficient amount of literature on this topic, there is a lack of systematic material on the subject of the study. Therefore, using various scientific cognition methods, information was analyzed, grouped, and systematized, and presented in the light of the research topic.

Purpose of the article

The aim of the article is to showcase technological solutions that increase the efficiency of solar panels.

Research results

As noted by Defend Solar USA Alliance [5], the development of a robust domestic solar energy production is crucial in the United States for ensuring energy independence and achieving climate goals. It is expected that by 2035, solar energy will account for 40% of the US energy balance, which requires a strong foundation of domestic production to maintain economic power and national security. The pace towards this goal increases yearly. The productivity and production volumes of solar power plants have significantly grown in recent years, made possible by several factors. One of the most important is technological progress in the production of solar panels and other components, which, firstly, reduces their cost and, secondly, improves technological efficiency. The technological race for new solar energy technologies is only intensifying. Each year sees the emergence of fundamentally new, innovative technologies that further enhance the technological component of this innovative energy sector [12].

By examining the scientific works of numerous specialists and researchers in the field of renewable energy, several new technologies introduced in the solar energy

sector in recent years can be identified [9].

Technological solutions that increase the efficiency of solar panels. The main key technological solutions used to enhance solar energy efficiency include the use of additional mirrors, Fresnel lenses, spherical concentrators, trackers, optimal solar panel placement technology, high-temperature materials, modular and hybrid solar systems (table 1).

Table 1 - Overview of technological solutions that increase the efficiency of solar panels

Technology	Description	Advantages
Use of additional mirrors	Mirrors placed near solar cells to enhance sunlight reflection	Increases output power by 35-60%, optimizes sunlight usage [9]
Flat Fresnel lenses	Focus light on photo cells, reducing their size while maintaining efficiency	Enhances light intensity, increasing power output; reduces physical size of photo cells [17]
Spherical concentrators	Effectively capture sunlight from various angles	Extends electricity production time, utilizes moonlight at night, improves energy efficiency by 27% [14]
Optimal placement of solar panels	Panels are positioned at angles that maximize sunlight absorption	Significantly boosts energy production by maximizing direct and reflected light absorption [4]
Use of trackers	Automatically adjust the position of solar panels according to the Sun's movement	Increases electricity generation by 50-55%, reduces panel temperature, effectively uses morning and evening hours [11]
High-temperature materials	Materials that withstand high temperatures without losing performance	Allow solar panels to operate efficiently at high temperatures, ensuring stability and longevity [6]
Modular systems with smart control	Integrated systems with automation to optimize energy production	Flexible production management, equipment status monitoring, adapts to weather changes and energy needs [2]

Note: systematized by the author

According to experts at Tamesol [13], the latest innovative technologies in solar energy promise a revolution in renewable energy sources, particularly due to advances in photovoltaic technologies. Key trends include increasing the efficiency of solar panels, expanding the use of bifacial panels that collect light from both sides, integrating photovoltaics into building materials, growing energy storage solutions, and the proliferation of "smart" solar systems.

Review of innovative solar energy production technologies. According to experts at Tamesol [13], the latest innovative technologies in solar energy promise a revolution in renewable energy sources, particularly due to advances in photovoltaic technologies. Key trends include increasing the efficiency of solar panels, expanding the use of bifacial panels that collect light from both sides, integrating photovoltaics into building materials, growing energy storage solutions, and the proliferation of "smart" solar systems.

Innovative overlapping photo cells by Mega Sunergy. The Taiwanese company Mega Sunergy has introduced a new photovoltaic module that revolutionizes the standard design of solar panels through a unique way of overlapping photo cells [7].

The new technology involves using 60 photo cells arranged so that their edges partially overlap, increasing the number of cells per unit area to 68. This has increased the overall efficiency of solar panels by 5-17%, depending on the type of solar cells used, despite a slight decrease in the performance of each individual cell.

Technically, the new photo cells, made from polycrystalline silicon, have a power output of 4.5 watts each and are sold at approximately 22.5 cents per watt. Adding 8 additional cells increases the total cost of the panel by $8.10, raising the cost per watt to 25 cents. This optimization allows Mega Sunergy to offer more efficient solutions for the solar energy market while maintaining competitive prices.

Perovskite solar panels. Perovskite solar panels represent a significant breakthrough in photovoltaics due to their exceptional characteristics and potential to reduce energy production costs. These cells are made from perovskite crystals, which provide high efficiency in converting sunlight into electricity, achieving over 25% efficiency, significantly surpassing many traditional silicon systems. The reliability and durability of perovskite panels against climatic changes and external conditions are also continually being improved, making them attractive for use in various geographic regions [16].

These cells also offer significant advantages in manufacturing processes, as they can be created using simpler technological methods such as spraying or printing. This opens up opportunities for reducing production costs and increasing the scale of application of these technologies in solar energy. The development and optimization of perovskite cells continue to be a focal point of scientific research, as they promise to revolutionize the solar energy market [16].

Transparent solar panels. Transparent solar panels are a significant innovation in the field of Building Integrated Photovoltaics (BIPV). These panels use special materials that allow light to pass through them, making the panels ideal for integration into architectural structures such as windows and glass facades of buildings. This technology not only enhances the aesthetic appearance of buildings but also provides additional efficiency by converting sunlight into electricity without losing natural lighting inside the premises.

Transparent solar panels differ from conventional applications in urban conditions where space for traditional panels is limited. The use of transparent photovoltaic technologies can significantly increase the potential for solar energy application in commercial and residential areas by integrating energy generation directly into building elements. Scientists are particularly focused on optimizing the transparency and efficiency of these panels, opening up new possibilities for design and engineering solutions [3].

Floating solar farms. Floating solar farms represent an innovative concept of installing solar panels on the surface of water bodies. This method of solar energy production has several important advantages, including the conservation of land resources and the reduction of water evaporation from reservoirs, which is critical in arid regions. Additionally, water naturally cools the panels, enhancing their efficiency and reducing the risk of overheating, which can negatively affect their performance and lifespan.

These technologies use floating platforms that can be installed on lakes, reservoirs, or other large water bodies. They not only provide sustainable energy production but also open new prospects for regions with limited access to free land plots. The development and implementation of floating solar farms also contribute to reducing environmental impact, as they minimize the need for land clearing and can be integrated into natural water systems with minimal anthropogenic impact [15].

Solar skins. Solar skins are an innovative technology that allows for the personalization of the appearance of solar panels, making them aesthetically pleasing and visually integrated into the architectural landscape. These skins can mimic the appearance of various materials such as brick, wood, or even grass, allowing solar panels to blend harmoniously into any architectural environment without losing their functionality. They are particularly useful in urban and residential areas where both high performance and visual appeal are important.

The technology of solar skins also promotes the broader acceptance of solar panels, as they are perceived less as industrial or technical elements. This opens new opportunities for designers and developers, providing them with the flexibility to create energy-efficient and visually attractive solutions for modern buildings. Moreover, innovations in materials and printing technologies allow these skins to be manufactured with high precision and customization for specific projects [8].

AI-based energy optimization systems. The use of artificial intelligence (AI) to optimize solar energy systems is one of the most advanced innovations in renewable energy production. AI allows for detailed analysis of energy production and consumption data, significantly enhancing the efficiency of energy resource management. Machine learning algorithms can predict peak loads, analyze weather conditions, and automatically adjust system operation to maximize solar energy utilization.

These technologies not only improve the performance of solar panels but also ensure their integration with other energy sources and the overall energy infrastructure [10].

Based on the provided information on specific innovative technologies in solar energy production, data can be structured in Table 2.

Future development technologies in solar energy for the coming years. Considering the prospects for the development of solar energy over the next decade, as outlined by several experts [1], it can be asserted that these prospects are shaped by a wide range of technical, economic, and political factors. Analyzing the forecasts, five stable directions remain unchanged: reducing the cost of solar panels, increasing their innovative and technological potential. Solar energy is likely to be actively implemented in various sectors of the national economy, with the innovative potential of solar power plants in logistics expected to activate soon.

Governments and legislative bodies worldwide are likely to continue supporting the adoption of solar energy through various measures, including financial incentives and renewable energy targets. This will stimulate further growth of the sector and the integration of solar energy into the global energy structure. Solar energy can play a significant role in improving access to electricity in developing countries, helping to reduce dependence on fossil fuels. The International Energy Agency (IEA) predicts

Table 2 – Innovative technologies in solar energy and their impact on energy extraction efficiency

Technology	Description	Impact on Efficiency
Innovative overlapping photo cells by Mega Sunergy	Uses 68 overlapping photo cells instead of the usual 60, increasing the number of cells per unit area	Increases overall efficiency of solar panels by 5-17%
Perovskite solar panels	Made from perovskite crystals, providing high efficiency in converting sunlight into electricity	Efficiency over 25%, reduces production costs
Transparent solar panels	Uses special materials that allow light to pass through, ideal for windows and glass facades	Integration into architectural structures without loss of natural lighting
Floating solar farms	Installation of solar panels on water surfaces, where water naturally cools the panels	Conserves land resources, increases efficiency
Solar skins	Customizes the appearance of solar panels, can mimic various materials	Enhances aesthetic and functional appeal
AI-based energy optimization systems	Uses machine learning algorithms to analyze and optimize energy production and consumption	Increases overall system productivity

Note: systematized by the author

that solar energy will become the main source of new electricity generation in these regions.

Considering these directions, it can be stated that solar energy will remain a key component of the global energy transition aimed at reducing greenhouse gas emissions and combating climate change.

Conclusions

Modern solar energy uses several technological solutions that significantly increase the efficiency of solar panels. The main ones include the use of additional mirrors, Fresnel lenses, spherical concentrators, optimal positioning of solar panels, trackers, high-temperature materials, as well as modular and hybrid solar systems. Innovations in this field include improving panel efficiency, expanding the use of bifacial panels, integrating photovoltaics into building materials, energy storage solutions, and the proliferation of "smart" solar systems, promising a revolution in renewable energy sources. Recent innovations in solar energy herald significant changes in the renewable energy sector, particularly due to advances in photovoltaic technologies. Key trends include increasing the efficiency of solar panels, implementing bifacial panels that collect light from both sides, integrating photovoltaics into building materials, growing energy storage solutions, and the spread of "smart" solar systems. Innovative solutions include Mega Sunergy's overlapping photo cells, which increase panel efficiency by 5-17%, the use of perovskite solar panels with over 25% efficiency, transparent solar panels for integration into windows and building facades, floating solar farms that conserve land resources and increase efficiency through water cooling, solar skins for aesthetic panel appeal, and AI-based energy optimization systems that boost performance by analyzing and adjusting system

operations. Future solar energy development technologies in the coming years anticipate a reduction in the cost of solar panels and an increase in their innovative potential. The active implementation of solar energy in various sectors of the national economy, including logistics, will be a key direction.

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