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# COMPARATIVE ANALYSIS OF CURRENT SOLAR TECHNOLOGIES AND PEROVSKITE SOLAR TECHNOLOGY

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## ABSTRACT

This research paper presents a comprehensive comparative analysis of various solar panel technologies such as monocrystalline, polycrystalline, thin-film (CdTe), PERC, and perovskite. The study is primarily concerned with important factors such as IV characteristics, efficiency, environmental factors, temperature coefficient, stability and durability, cost and manufacturability, light trapping technique, advantages, and challenges. The results show that there are considerable differences in the performance parameters between the various solar panel technologies. While polycrystalline panels provide more affordable options, monocrystalline and PERC panels have higher efficiency and power outputs. Thin film technology demonstrates advantages in material usage and cost reduction. Perovskite panels have improved efficiency, but stability issues remain. Environmental factors, including changes in temperature tolerance, humidity resistance, and light-level adaptability, have an impact on panel performance. Light trapping mechanisms differ among technologies, leveraging crystal structures, specialized materials, and optimized architectures. This research provides valuable insights into the strengths and limitations of different solar panel technologies, assisting stakeholders in making the right choices depending on their specific needs and environmental conditions. The study underscores the potential of perovskite technology for future development, while acknowledging the ongoing need for further research to enhance its stability and long-term performance.

**Keywords:** Solar technology, perovskite solar technology, IV characteristics, light trapping mechanism.

## I. INTRODUCTION

The Solar cell technology has advanced significantly as a result of the growing global demand for clean and sustainable energy. Solar energy, as a renewable and abundant resource, holds immense potential for addressing our ever-growing energy needs while minimizing environmental impact. Over the years, the silicon-based solar cells that are the foundation of today's solar technology have advanced significantly, enabling widespread commercial use and cost reduction. The development of perovskite solar technology has attracted significant attention due to its unique properties and potential for enhanced performance [1]. Silicon-based solar cells, commonly referred to as current solar technology, have dominated the photovoltaic industry for several decades. These cells benefit from the maturity of silicon processing techniques and established manufacturing infrastructure, leading to economies of scale and cost reductions. Silicon cells exhibit well-characterized electrical behavior, with well-defined current-voltage (IV) characteristics. They are useful for large-scale power generation in a variety of applications due to their great efficiency and dependability [2]. Perovskite solar cells, on the other hand, are a potential alternative that are built on a hybrid organic-inorganic material. The name "Perovskite" comes from the nickname for their crystal structure. Perovskite solar cells utilize a unique class of materials with a perovskite crystal structure, typically composed of metal halides such as methyl ammonium lead iodide (CH3NH3PbI3). One of the key advantages of perovskite solar cells is their remarkable power conversion efficiency. Perovskite solar cells have seen significant efficiency improvements over the last ten years, with laboratory-scale systems exceeding 25% [3]. The tunable bandgap of perovskite materials, which enables effective absorption of a wide variety of sunlight wavelengths, is chiefly responsible for this quick advancement. Additionally, perovskite solar cells benefit from low fabrication costs, as they can be produced through scalable solution-based processes such as spin-coating or inkjet printing [4]. The rapid progress in perovskite solar technology has resulted in impressive efficiency improvements, approaching the performance levels of silicon cells in a short period of time. However, challenges related to stability, moisture sensitivity, and long-term durability still need to be addressed to ensure their economic viability [5]. By comparing the performance metrics of efficiency, power output, and electrical parameters such as open circuit voltage (Voc) and short circuit current

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(Isc), we can assess the relative strengths and weaknesses of these two technologies. The figure 1 shows the typical representation of perovskite solar cell [6].

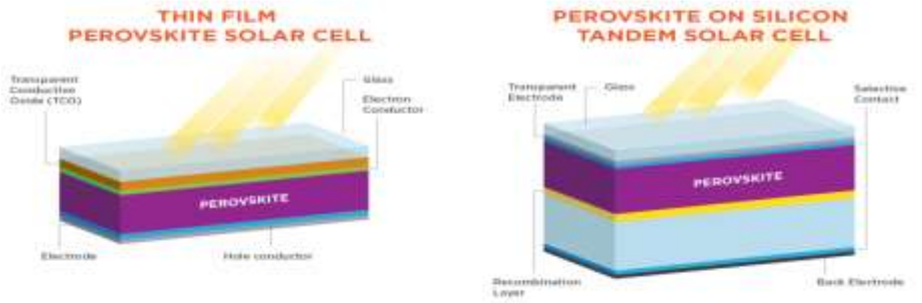


**Fig 1:** Perovskite Solar cell

In recent years significant improvements have been made in both established solar technologies and new ones, including perovskite solar cells. In order to give a comprehensive picture of the state of research and development in these two fields, this literature assessment will compare and contrast each field's essential qualities. Current solar technology, represented by monocrystalline, polycrystalline, PERC and thin-film solar panels, has been extensively studied and deployed worldwide [7]. Monocrystalline solar panels, known for their high efficiency and power output, have dominated the market due to their superior electrical properties. Numerous research have examined how improvements in material quality, surface passivation methods, and light-trapping structures can improve monocrystalline cells [8]. Due to its affordability and feasibility for large-scale installations, polycrystalline and thin-film solar panels have also drawn attention. Through advancements in material composition, device structure, and deposition techniques, researchers have concentrated on improving their effectiveness, stability, and manufacturability [9]. The comprehensive review article on "Perovskite Solar Cells: An Emerging Photovoltaic Technology" by NREL (National Renewable Energy Laboratory) (2015) provides an overview of the state-of-the-art in perovskite solar cell research. It discussed the advancements in materials, device architectures, and fabrication techniques, as well as the challenges and future prospects of perovskite technology. Comparative analysis has revealed the strengths and weaknesses of each technology, providing valuable insights for system design, manufacturing, and market adoption [10]. This paper aims to provide a comprehensive comparative analysis of current solar technology and perovskite solar technology. It delves into various aspects, including efficiency, power output, cost considerations, electrical parameters, environmental conditions, stability and durability, performance under varying conditions, light trapping mechanism, cost, manufacturability, as well as the associated benefits and challenges. This paper aims to provide a thorough comparison of current solar technology and perovskite solar technology. It explores various aspects, including efficiency, power output, cost considerations, electrical parameters, environmental conditions, stability and durability, performance under varying conditions, light trapping mechanism, cost, manufacturability, as well as the associated benefits and challenges. In subsequent sections of this paper, I will examine each of the abovementioned factors and by examining these key factors, I seek to evaluate the strengths and limitations of each technology, thus providing valuable insights into their potential applications and future development. This paper also aims to provide researchers, industry professionals, and policymakers with a comprehensive understanding of the current solar technology and perovskite solar technology landscape. Such knowledge will facilitate informed decision-making, guiding future research directions, and enabling the efficient deployment of solar energy technologies. Through this analysis, I hope to shed light on the potential of perovskite solar technology and its role in shaping the future of solar energy generation.

## II. CHARACTERISTICS

The current-voltage (IV) characteristic of a solar panel is a fundamental parameter that describes its electrical behavior and performance. The relationship between the current (I) flowing through the solar panel and the voltage (V) across its terminals is represented by the IV characteristic curve. This curve provides an insightful information about the panel's behavior under different operating conditions and helps assess its efficiency and power output. The curve shown in figure 2 represents the IV characteristics of a solar panel. The IV characteristic of a solar panel typically exhibits a distinctive shape, starting from the open circuit voltage (Voc) where no current

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flows, gradually increasing current as the voltage drops, reaching a maximum power point (MPP), and then rapidly decreasing as the voltage approaches the short circuit current (Isc). The shape of the IV curve is determined by the physical properties of the solar cells, including the materials used, their energy bandgap, and the presence of recombination and resistive losses [11].

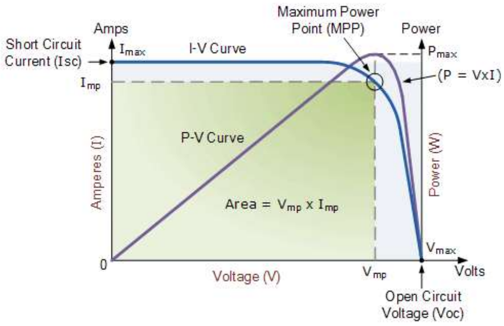


**Fig 2:** IV curve of solar panel [12]

Monocrystalline panels typically exhibit well-defined IV curves with higher open circuit voltages (Voc) and short circuit currents (Isc). Compared to other technologies, this leads to improved overall efficiency and power production. On the other hand, polycrystalline panels have slightly lower Voc and Isc values, which results in slightly lower efficiency and power output. Despite having a lower overall efficiency, thin-film panels operate better in low-light or high-temperature conditions thanks to their distinctively larger and smoother IV curve shape. In comparison to traditional solar cells, PERC panels have a high open circuit voltage (Voc) and an enhanced maximum power point (MPP). This is achieved through the implementation of a passivated rear contact, reducing recombination losses and increasing power output. As for perovskite solar panels, their IV characteristics have shown rapid advancements, with high Voc and Isc values comparable to monocrystalline silicon panels. Perovskite technology has shown the potential to rival conventional technologies in terms of high efficiencies and power outputs. Continued research is focused on improving stability and durability while maintaining their exceptional IV characteristics. The below table shows the typical values of parameters for different solar cells under T = 25°C cell temperature and 1000 ($W/m^2$) irradiations.

**Table 1:** IV characteristics of solar cell

| Parameter | Monocrystalline | Polycrystalline | PERC | Thin film (CdTe) | Perovskite |
|---|---|---|---|---|---|
| Isc (volts per cell) | 0.6 | 0.55 | 0.65 | 0.7 | 0.9 to 1.1 |
| Voc ($A/m^2$) | 9 | 8 | 9 | 12 | 15 to 20 |
| Mpp ($A/m^2$) | 7.5 | 6.5 | 7.5 | 10 | 12 to 16 |

**Equations**

The IV characteristics of perovskite solar cells can be described using the diode equation, similar to current solar technology. However, the specific parameters and behavior may differ due to variations in material properties and device architecture. The IV characteristics of current solar technology, typically represented by silicon-based solar cells, follow the diode equation. The diode equation describes the relationship between the current (I) flowing through the solar cell and the voltage (V) applied across it. The equation is given as:

$$I = I_l - Io\left[e^{\left(\frac{V+I.Rs}{n.Vt}\right)} - 1\right] - \frac{V+I.Rs}{Rsh} \quad \text{...... (1)}$$

Where, I: Current (A), V: Voltage (V), $I_l$: Light-generated current (A), *Io*: Reverse saturation current (A), Rs: Series resistance (Ω), n: Ideality factor, Vt: Thermal voltage (V), Rsh: Shunt resistance (Ω).

The IV characteristics play a vital role in determining the efficiency and power output of a solar cell. The efficiency (η) of a solar cell is defined as the ratio of the maximum power output (Pmax) to the incident light power (Pin), expressed as a percentage:

$$\eta = \left(\frac{Pmax}{Pin}\right).100 \quad ......(2)$$

The power output (P) of a solar cell can be calculated as the product of the current (I) and voltage (V) at any given point on the IV curve:

$$P = I.V \quad ......(3)$$

## III. EFFICIENCY

Higher efficiency solar panels can generate more electricity for a given amount of sunlight, maximizing the power output and overall performance of the system. Improvements in solar panel efficiency are crucial for enhancing the viability of solar energy as a sustainable and economically competitive alternative to conventional energy sources. The efficiency of conventional solar technologies, such as monocrystalline and polycrystalline silicon-based panels, has significantly increased over time. For monocrystalline panels, these technologies typically attain efficiency levels between 15% and 22%, and for polycrystalline panels, between 13% and 18%. Thin-film solar panels have lower efficiencies compared to crystalline silicon panels. However, thin-film technology offers other advantages such as flexibility, lightweight, and improved performance under diffuse or low-light conditions. Current thin-film technologies achieve efficiency levels ranging from 7 to 16% [13]. Perovskite materials have demonstrated remarkable efficiency improvements in a relatively short period. Recent research and development efforts have shown perovskite solar cells achieving efficiencies above 25% and even exceeding 28%. The figure 3 perfectly describes the efficiency comparison of different PV cells. This rapid progress positions perovskite technology as a potential game-changer in the solar industry. The unique properties of perovskite materials, such as their high light absorption and tuning ability, contribute to their high-efficiency performance. First off, they maximize the power output of solar arrays by enabling increased electricity generation per unit area. This is especially advantageous in situations with limited space, like rooftop installations or places with high energy demand. Additionally, as more electricity may be produced with the same initial capital input, higher efficiency enables a quicker return on investment. Additionally, high-efficiency solar panels can help reduce the overall cost of solar energy and accelerate the transition towards a clean and sustainable energy future. Table 2 shows the typical efficiency and power output comparison for different solar cells with typical size 156 mm x156 mm under T = 25°C cell temperature and 1000 (W/m²) irradiations.

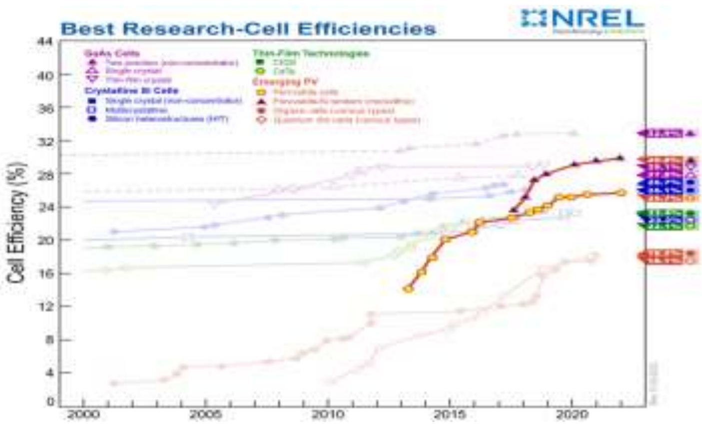


**Fig 3:** Efficiency comparison of different PV cells [14]

**Table 2:** Efficiency and Power Output of solar cell

| Parameter | Monocrystalline | Polycrystalline | PERC | Thin Film (CdTe) | Perovskite |
|---|---|---|---|---|---|
| **Efficiency (%)** | 20 | 16 | 22 | 16 | 25 |
| **Power Output (W)** | 5.5 | 4.5 | 5.5 | 3.5 | 8 |

## IV. ENVIRONMENTAL CONDITIONS

Different types of solar panels perform differently depending on the varying environmental conditions. Monocrystalline and polycrystalline panels are well known for their ability to handle heat in high temperatures. They have a lower temperature coefficient, resulting in less efficiency loss compared to other technologies. Thin-film panels, particularly those based on amorphous silicon (a-Si), also perform well in high temperatures and have a higher tolerance to heat. PERC panels, with their passivation layers, exhibit improved performance and minimize efficiency loss in high-temperature environments. Even though they are still in the research and development stage, perovskite solar panels have promising thermal stability and efficiency characteristics. When it comes to humidity and moisture, monocrystalline and polycrystalline panels are designed with a sealed construction to withstand high humidity levels and protect internal components from moisture damage. Thin-film panels, including perovskite-based ones, may have varying levels of moisture resistance depending on their specific design and manufacturing techniques. Manufacturers implement sealing techniques to enhance durability and ensure resistance to moisture ingress. PERC panels, specifically engineered with improved moisture resistance, are suitable for environments with higher humidity levels. Regarding varying levels of sunlight, monocrystalline and polycrystalline panels perform well under different light conditions, but shading of individual cells or modules can significantly affect overall power output [15]. Thin-film panels, including perovskite-based ones, generally have a higher tolerance to shading, allowing them to maintain relatively higher power output even in partially shaded conditions. PERC panels are designed to handle shading conditions effectively, ensuring improved performance in low-light environments. Being a relatively new technology, perovskite panels have shown the capacity to produce power from diffuse or indirect sunlight and have the potential to remain effective even in low-light conditions. The table 3 represents the performance of solar panels under varying environmental conditions.

**Table 3:** Performance under varying environmental conditions

| Solar Panel Types | High Temperature | Humidity and Moisture | Varying Levels of Sunlight |
|---|---|---|---|
| **Monocrystalline** | Stable performance | Sealed construction | Affected by shading |
| **Polycrystalline** | Handles well | Sealed construction | Affected by shading |
| **PERC** | Better performance | Sealing techniques | Tolerates shading |
| **Thin Film (CdTe)** | Improved performance | Enhanced moisture | Handles shading well |
| **Perovskite** | Promising performance | Moisture resistance | Efficient in low light |

## V. TEMPERATURE COEFFICIENT

Solar panel technologies have different temperature coefficients, which describe how their performance is affected by temperature changes. Temperature coefficients for monocrystalline and polycrystalline panels are typically between -0.3% and -0.5% per degree Celsius. These panels can withstand temperature changes reasonably well, and as temperatures rise, their efficiency declines more slowly. However, their power output still decreases with higher temperatures, impacting overall system performance and energy production. Thin-film panels, on the other hand, have higher temperature coefficients compared to crystalline silicon panels. Thin-film panels experience a greater reduction in efficiency with increasing temperatures, their initial efficiency is often lower, mitigating the overall impact of temperature fluctuations on energy production. Cadmium telluride (CdTe) demonstrate a relatively lower temperature coefficient, resulting in better performance in high-temperature conditions. Cadmium Telluride's (CdTe) temperature coefficient normally ranges from -0.20% to -0.30% per degree Celsius. The temperature coefficients of PERC panels, designed with improved technology, are typically between -0.35% and -0.45% per degree Celsius [16]. PERC panels demonstrate improved performance in high-temperature environments, experiencing lower efficiency loss as temperatures rise. This ensures a higher level of energy production even under hot conditions. Perovskite technology is still undergoing research and development, and its temperature coefficient can vary depending on the specific composition and formulation. However, recent advancements in perovskite materials have shown promising results, with temperature coefficients comparable to or better than traditional crystalline silicon panels. Perovskite panels have shown the potential to maintain efficiency even at extreme temperatures, making them a promising option for high-temperature environments. The temperature coefficient of perovskite solar cells typically ranges from -0.25% to -0.35% per degree Celsius. Table 4 shows the typical values of temperature coefficient of solar panels.

**Table 4:** Temperature Coefficient of solar panels

| | **Monocrystalline** | **Polycrystalline** | **PERC** | **Thin Film (CdTe)** | **Perovskite** |
|---|---|---|---|---|---|
| **Temperature Coefficient (%)** | -0.3 to -0.5 | -0.3 to -0.5 | -0.20 to -0.30 | -0.35 to -0.45 | -0.25 to -0.35 (Typical) |

## VI. STABILITY AND DURABILITY

Stability and durability play a critical role in maximizing the performance, reliability, and economic viability of solar panels, while also contributing to the sustainability and environmental benefits of solar power. Stable panels maintain consistent electrical output and conversion efficiency over time, ensuring predictable and reliable energy generation. By maintaining performance and functionality, stable panels reduce the risk of performance degradation and revenue losses, optimizing the financial benefits of solar power. Additionally, stable and durable panels contribute to the sustainability of renewable energy systems by minimizing waste, reducing maintenance needs, and reducing the environmental impact associated with the production and disposal of panels. Durability allows panels to withstand physical stresses, extreme weather conditions, and environmental factors without significant damage or loss of functionality. Monocrystalline panels are well known for their stability because they have a low risk of performance degradation over time. The monocrystalline panels long-term durability is a result of the great purity of the crystalline silicon material employed in those panels. In general, monocrystalline panels are strong and resistant to a variety of environmental factors, including temperature changes and mechanical pressures. Long-term durability is ensured by the strong frame and impact-resistant front made of tempered glass. Polycrystalline panels are regarded as stable and have a low chance of losing performance over time. While their efficiency may be slightly lower than monocrystalline panels, polycrystalline panels still offer reliable and consistent energy generation. Polycrystalline panels are known for their durability and resistance to environmental factors. They can withstand temperature fluctuations, extreme weather conditions, and mechanical stresses, ensuring their long operational life. Both Monocrystalline and Polycrystalline panels are typically designed to last for 25 to 30 years. PERC panels are designed to enhance stability and reduce the risk of degradation. The passivation layers in PERC cells improve carrier recombination, resulting in better stability and long-term performance. Similar to conventional crystalline silicon panels in terms of robustness, PERC panels have good durability. Their capacity to survive harsh climatic conditions is ensured by the combination of a sturdy module design and high-quality materials.

Thin-film panels can exhibit slightly lower stability compared to crystalline silicon panels. Over time, there may be a gradual decrease in performance due to potential degradation of the thin-film materials. Thin-film panels vary in durability depending on the specific materials used, such as amorphous silicon (a-Si), cadmium telluride (CdTe), or copper indium gallium selenide (CIGS). CdTe thin-film panels, for example, are known for their good durability and resistance to moisture and temperature fluctuations. Perovskite panels are still undergoing extensive research and development to improve their stability. Compared to the most leading photovoltaic (PV) technology, their stability is limited. Perovskites can decompose when they react with moisture and oxygen or when they spend extended time exposed to light, heat, or applied voltage. Researchers are investigating degradation in both the perovskite material itself and the surrounding device layers to boost stability. For the development of commercial perovskite solar products, improved cell endurance is essential. Durability is a key area of focus in perovskite panel research. Efforts are being made to enhance the encapsulation and protective layers to improve their resistance to environmental factors and extend their operational life. For commercial, grid-level electricity production, perovskite PV research and development (R&D) community is targeting an operational lifetime of at least 20 years, and preferably more than 30 years [17]. The table 5 shows the comparison of stability and durability of different solar panels.

**Table 5:** Stability and Durability of solar panels

| Solar Panel Types | Stability | Durability |
|---|---|---|
| **Monocrystalline** | High | High |
| **Polycrystalline** | High | High |
| **PERC** | Enhanced | Good |
| **Thin Film (CdTe)** | Moderate | Good |
| **Perovskite** | Developing | Developing |

## VII. COST AND MANUFACTURABILITY

Cost and manufacturability are vital factors in the development and deployment of solar panels. Lowering the cost of solar panels allows for more affordable solar energy systems, making them accessible to a broader range of consumers and facilitating their adoption on a larger scale. Enhancing the manufacture of solar panels also provides dependable performance, increased production yields, and lower manufacturing costs. It helps solar panel producers to meet the demand for solar panels in massive projects and makes it easier to incorporate solar energy into many applications, like home, business, and utility-scale installations. Monocrystalline panels are generally considered to have a higher cost compared to other technologies due to the more intricate manufacturing process and the higher purity of silicon required.

The compatibility with existing production equipment and infrastructure streamlines manufacturing and allows for efficient scale-up. Polycrystalline panels are typically more cost-effective compared to monocrystalline panels. The production process involves less refining of the silicon material, resulting in lower manufacturing costs. Polycrystalline panels share similarities in manufacturing processes with monocrystalline panels. The lower purity silicon used in polycrystalline cells allows for simpler and less energy-intensive manufacturing steps. PERC panels, which are an upgrade to conventional crystalline silicon cells, may have slightly higher manufacturing costs due to the additional process steps required to introduce passivation layers. PERC technology builds upon existing crystalline silicon cell manufacturing processes with minimal changes. This enables effective integration into current production lines by utilizing the knowledge and resources that are already in place for conventional cells. Thin-film panels have the potential for lower manufacturing costs compared to crystalline silicon panels. The material efficiency and the possibility of using roll-to-roll deposition processes offer potential cost advantages.

Thin-film technologies typically involve deposition processes, such as vacuum deposition or sputtering, which can require specialized equipment and production techniques. Achieving high production yields and ensuring consistent performance across large areas are ongoing challenges in thin-film manufacturing. Perovskite panels are still in the early phases of development, and as the technology develops and economies of scale are realized, their cost is anticipated to decline. Initial manufacturing costs may be higher due to the need for specialized materials and deposition processes. Perovskite manufacturing processes are still being optimized to achieve high production yields and scalability. Challenges related to stability, reproducibility, and scaling up from small laboratory-scale cells to larger panels need to be addressed.

## VIII. LIGHT TRAPPING MECHANISM

Monocrystalline and polycrystalline panels utilize textured surfaces as their primary light trapping mechanism. The tiny or nanostructured patterns on these surfaces contribute to lengthening the path of light within the semiconductor material. The effectiveness of monocrystalline and polycrystalline panels is considerably improved by textured surfaces because they decrease light reflection and increase light absorption. On the other side, thin-film panels use many layers and grating designs to improve light trapping. These panels are made of several semiconducting layers with various refractive indices. This design creates an optical interference effect that traps light within the thin-film structure, improving light absorption. Additionally, grating structures can be incorporated into the panel design to further enhance light trapping. The use of multiple layers and grating structures in thin-film panels allows for the use of thinner absorber layers, reducing material costs and increasing manufacturing efficiency.

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PERC (Passivated Emitter and Rear Cell) panels utilize a combination of rear surface passivation techniques and textured surfaces to optimize light trapping. Rear surface passivation involves adding a dielectric layer at the rear side of the solar cell to minimize recombination and improve light absorption. Light trapping is further improved by surfaces with texture, such as those seen in monocrystalline and polycrystalline panels. Rear surface passivation and textured surfaces work together to improve the efficiency of PERC panels by reducing recombination losses and increasing light absorption. Perovskite panels employ micro/nanostructured interfaces and tandem structures to enhance light trapping and absorption. The micro/nanostructured interfaces within the perovskite layer help trap and scatter light, increasing the chances of absorption. Additionally, tandem structures combine different materials with complementary absorption properties to maximize light absorption across a wider range of the solar spectrum [18].

By utilizing these light trapping mechanisms, perovskite panels aim to achieve higher efficiency by capturing a larger portion of the incident sunlight.

## IX. BENEFITS AND CHALLENGES

Monocrystalline panels offer higher efficiency and are space-efficient which makes them ideal for rooftops with limited area. However, their upfront cost are high due to their precise crystal growth manufacturing process. Polycrystalline panels, on the other hand, have a lower upfront cost compared to monocrystalline panels, making them a more affordable option. While their efficiency is slightly lower, they are widely available in the market, providing consumers with more options. PERC panels have increased efficiency and better performance in low light conditions. They have layers of passivation that boost overall power output.

However, PERC panels may cost more due to the additional materials and manufacturing processes required. Thin-film panels offer flexible installation options, as they are lightweight and can be installed on curved or irregular surfaces. They also handle high temperatures better than crystalline panels, resulting in less efficiency loss. However, their lower efficiency requires more installation space, and some thin-film materials may experience gradual degradation over time. Perovskite panels show potential for high efficiency and versatility. They can be converted into flexible, light-weight, and semi-transparent panels and have proven to be highly efficient in laboratory settings. However, their stability and durability are still being researched and improved, and scaling up production while maintaining cost-effectiveness remains a challenge. The below Table compares the benefits and challenges of different solar panel types.

**Table 6:** Benefits and Challenges of solar panels

| Solar Panel Types | Benefits | Challenges |
|---|---|---|
| **Monocrystalline** | Higher Efficiency | Higher Cost |
| | Space efficient | Manufacturing complexity |
| **Polycrystalline** | Lower cost | Slightly lower efficiency |
| | Widely available | Space requirements |
| **PERC** | Enhanced efficiency | Higher cost |
| | Improved performance in low light conditions | Manufacturing complexity |
| **Thin Film** | Flexible Installations | Lower efficiency |
| | Better high temperature performance | Degradation over time |
| **Perovskite** | Potential for high efficiency | Stability and durability |
| | Versatility in Panel design | Cost and scalability |

## X. RESULT AND DISCUSSION

In this study, I conducted a comprehensive analysis and comparison of various solar panel technologies, including monocrystalline, polycrystalline, thin-film (CdTe), PERC, and perovskite, focusing on their IV characteristics, efficiency, cost, manufacturability, stability, durability, light trapping mechanisms, and temperature coefficients.

Efficiency plays a crucial role in deciding how well solar panels work. In comparison to polycrystalline and thin-film panels, monocrystalline and PERC panels had better efficiency. With their single-crystal structure, monocrystalline panels displayed greater electron mobility, leading to higher conversion efficiencies. By lowering recombination losses, PERC panels with rear surface passivation and textured surfaces obtained higher efficiencies. Perovskite panels showed promise in attaining high efficiencies due to their exceptional light absorption properties and tunable bandgaps.

Efficiency and size of the panel have a direct impact on power production. When compared to other technologies, monocrystalline panels, which are recognized for their high efficiency, often provided larger power outputs. However, the size and number of panels in a system also play a crucial role in determining the overall power output. Cost and manufacturability are key considerations for large-scale deployment of solar panels. Monocrystalline and polycrystalline panels have been widely adopted and benefit from mature manufacturing processes, resulting in relatively lower costs. Thin-film technologies, such as CdTe, offer advantages in terms of material usage and potential cost reductions. Perovskite panels have shown significant cost reduction potential, but their commercial viability and long-term cost-effectiveness are still being evaluated.

The manufacturability of each technology depends on factors such as material availability, production scalability, and process complexity.

Monocrystalline and polycrystalline panels have demonstrated stability and durability with lifespans exceeding 25 years. Thin-film panels, including CdTe, have demonstrated good stability and durability under various environmental conditions. However, issues with moisture infiltration and temperature stability might need to be resolved. Perovskite panels have shown rapid efficiency improvements but are still in the early stages of development, with stability and durability being active areas of research. Light trapping mechanisms are employed by different technologies to enhance light absorption. Monocrystalline and polycrystalline panels utilize textured surfaces to lengthen the path of light within the semiconductor material, resulting in enhanced absorption. Thin-film panels utilize multiple layers and grating structures to optimize light trapping, leveraging the optical interference effect.

PERC panels combine rear surface passivation with textured surfaces to reduce recombination losses and enhance light absorption. Perovskite panels employ micro/nanostructured interfaces and tandem structures to maximize light absorption across a wide solar spectrum. Temperature coefficients play a crucial role in determining the impact of temperature fluctuations on panel performance. Monocrystalline, polycrystalline, and PERC panels generally exhibited temperature coefficients around -0.3% to -0.5% per degree Celsius. Temperature coefficients for CdTe thin-film panels typically ranged from -0.20% to -0.30% per degree Celsius. The typical temperature coefficient for perovskite solar cells was between -0.25% and -0.35% per degree Celsius.

## XI. CONCLUSION

In conclusion, monocrystalline and PERC panels showed better efficiencies, and due to their superior performance, monocrystalline panels showed higher power outputs. In terms of cost and manufacturability, monocrystalline and polycrystalline panels benefit from mature manufacturing processes, resulting in relatively lower costs. CdTe is one example of a thin-film technology that has advantages in terms of material utilization and potential cost savings. Perovskite panels showed great promise, with impressive efficiency improvements and remarkable low-light performance.

However, stability, durability, and long-term performance of perovskite panels remain active areas of research and development. Future efforts should focus on enhancing the stability, scalability, and cost-effectiveness of perovskite manufacturing, as well as exploring novel light trapping mechanisms. Continued advancements across these technologies will contribute to the growth and evolution of the solar energy industry, paving the way for a sustainable and clean energy future.

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## XII. REFERENCES

[1] N. S. Kumar and K. Naidu, "A review on perovskite solar cells (PSCs)," Journal of Materiomics, vol. 7, no. 5, pp. 940-956, 2021 Sep 1.

[2] S. Kim, V. Hoang and C. Bark, "Silicon-based technologies for flexible photovoltaic (Pv) devices: From basic mechanism to manufacturing technologies," Nanomaterials, vol. 11, no. 11, p. 2944, 2021.

[3] Perovskite solar cells: Background and prospects for space power applications," Elsevier, pp. 129-156, 2023.

[4] J. Kim, J. Lee, H. Jung, H. Shin and N. Park , "High-efficiency perovskite solar cells," Chemical Reviews, vol. 120, no. 15, pp. 7867-7918, 2020.

[5] D. Kim, J. Lee, R. Jeong and J. Boo, "A high-efficiency and stable perovskite solar cell fabricated in ambient air using a polyaniline passivation layer," Scientific Reports, vol. 12, no. 1, p. 697, 2022.

[6] "Department Of Energy," [Online]. Available: https://www.energy.gov/eere/solar/perovskite-solar-cells.

[7] Upadhyay and A. Chowdhury, "Solar Energy Fundamentals and Challenges in Indian," International Journal of Scientific and Research Publications, vol. 4, no. 10, pp. 1-13, 2014.

[8] J. Zhou, Y. Tan, W. Liu, X. Cai, H. Huang and Y. Cao, "Effect of front surface light trapping structures on the PERC solar cell," SN Applied Sciences, vol. 2, pp. 1-10, 2020.

[9] R. Parthiban and P. Ponnambalam, "An Enhancement of the Solar Panel Efficiency: A Comprehensive Review," Frontiers in Energy Research, vol. 10, p. 937155, 2022.

[10] N. Park, "Perovskite solar cells: an emerging photovoltaic technology," Materials Today, vol. 18, no. 2, pp. 65-72, 2015.

[11] Y. Sun, C. Yuan and X. Yan, "Theoretical model research on I-V characteristics of solar cell under the marine environment," in International Conference on Transportation Information and Safety (ICTIS), Wuhan, 2015.

[12] "National Institute of Science Education and Research," [Online]. Available: https://www.niser.ac.in/.

[13] G. Nanda, R. Dash, S. Swain and R. Kumar, "A Comparative Study on Different Types of PV Modules and Their Optimization for Increasing the Efficiency Part-I," in Second International Conference on Computational Intelligence & Communication Technology (CICT), Ghaziabad, 2016.

[14] National Renewable Energy Laboratory (NREL)," [Online]. Available: https://www.nrel.gov/pv/perovskite-solar-cells.html.

[15] M. Das, "Effect of Different Environmental Factors on performance of solar panel," International Journal of Innovative Technology and Exploring Engineering, vol. 8, no. 11, pp. 15-18, 2019.

[16] M. Jošt, B. Lipovšek, B. Glažar, A. Al-Ashouri, K. Brecl, G. Matič and S. Albrecht, "Perovskite Solar Cells go Outdoors: Field Testing and Temperature Effects on Energy Yield," Advanced energy materials, vol. 10, no. 25, p. 2000454, 2020.

[17] Y. Wang, I. Ahmed, T. Leung, J. Lin, W. Chen, F. Liu and A. Djurišić, "Encapsulation and Stability Testing of Perovskite Solar Cells for Real Life Applications," ACS Materials Au, vol. 2, no. 3, pp. 215-236, 2022.

[18] Tooghi, D. Fathi and M. Eskandari, "Numerical study of a highly efficient light trapping nanostructure of perovskite solar cell on a textured silicon substrate," Scientific Reports, vol. 10, no. 1, pp. 1-13, 2020