



Solar Photovoltaic Technologies and Advancements

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ABSTRACT :

Photovoltaic (PV) technology has evolved significantly, transforming solar energy generation. This overview highlights recent advancements, focusing on enhanced efficiency, affordability, and accessibility. It begins with PV technology's introduction, emphasizing its role in solar energy generation. Efficiency improvements stem from novel materials, cell architectures, and manufacturing techniques, impacting performance and cost-effectiveness. Innovations like roll-to-roll printing and thin-film deposition contribute to scalability and cost reduction. Integration with energy storage, including advancements in batteries and management systems, is crucial. Solar tracking systems and concentrator technologies optimize energy capture. Environmental considerations, from manufacturing to disposal, are addressed, with recycling initiatives and eco-friendly materials mitigating impacts. Economic factors and policy frameworks, such as cost trends and incentives, drive PV adoption. Challenges ahead include stability, cost reduction, and grid integration. On-going research promises future advancements in PV technology.

Index Terms :template, Scribbr, IEEE, format SOLAR PHOTOVOLTAIC TECHNOLOGIES

Introduction :

The direct conversion of sunlight to electrical energy can be termed as Photovoltaics.

In the year 1839, Edmond Becquerel created the world's first photovoltaic cell. The main component of the solar photovoltaic technologies are photovoltaic cells, which is also known as solar cells. These cells convert the solar energy into electrical energy. The solar cell is small in size which can produce 1 or 2 watts of power. These cells are protected from the outdoors by plastics or glass placed above and below them usually sandwiched between glass or plastic for the protection. It is renewable and rapidly growing in today's world it can be used as an alternative to the traditional fossil fuel electricity generation method.

Structure of solar photovoltaics

Photovoltaic solar cell: Cells are the main component they trap the sunlight and convert them into electricity.

Front glass: Its function is to protect the photovoltaic module, maintaining a high transparency. Their thickness are in millimeters usually 2 to 4mm.

Back-sheet: It is made from a plastic material that protects and provides isolation to the PV cells from weather and moisture.

Encapsulant material: The function is that it acts as a binder between the various layers of the PV panel. The most common material used as an encapsulant is EVA – Ethylene vinyl acetate.

Frame: One of the last parts. The frame has the function to ensure safe coupling and robustness to the photovoltaic module. Usually made of aluminum.

Different mounting structures in solar photovoltaic technology

1. **Rooftop Solar Mounting Structure:** Its roof mounted solar structure. In this system the main structure of the solar panel is at the rooftop which reduces the cost, its cost friendly.
 - Sloped Roof
 - Flat Roof
2. **Ground Mounted Solar Systems:** In this system the structures are placed on ground. This system provides a wide variety of installation options depending on needs, designs and locations. The options are mentioned below.
 - Foundation mounts
 - Ballasted Footing Mounts
 - Pole Mounts
 - Multi-Pole Mounts

3. Smart Flower
4. *Top of The Pole Mounts*: The entire structure is mounted on a pole.They have strong backs,elevated pivots.They can be tilted and they can with stand strong weather.
5. *Side Pole Mounts*: These mounts are mostly used for very small solar panel installations and lightning purposes.
6. *Tracking System Mounted Racks*: one-axis and two-axis. The one-axis trackers track the sun’s movement from the east to the west. On the other hand, the two-axis systems track the daily and seasonal course of the sun.

Components Required For Mounting

1. Solar Panel Mounting Brackets
2. Solar Panel Mounting Clamps
3. Solar Panel Mounting Strut Channel
4. Solar Panel Mounting Screw
5. No Drill Solar Panel Roof Mounts
6. Solar Panel Roof Mounting Aluminum Rail
7. Solar Panel Mounts for Shingle Roof

SCOPE OF SOLAR PHOTOVOLTAIC TECHNOLOGY

The worldwide growth of photovoltaics is extremely dynamic and varies strongly by country. In April 2022, the total global solar power capacity reached 1 TW.[3] In 2022, the leading country for solar power was China, with about 390 GW.(4)(5) account for nearly two- fifths of the total global installed solar capacity. As of 2022, there are further than 40 countries around the world with a accretive PV capacity of further than one gigawatt, including Canada, South Africa, Chile, the United Kingdom, South Korea, Austria, Argentina and the Philippines.

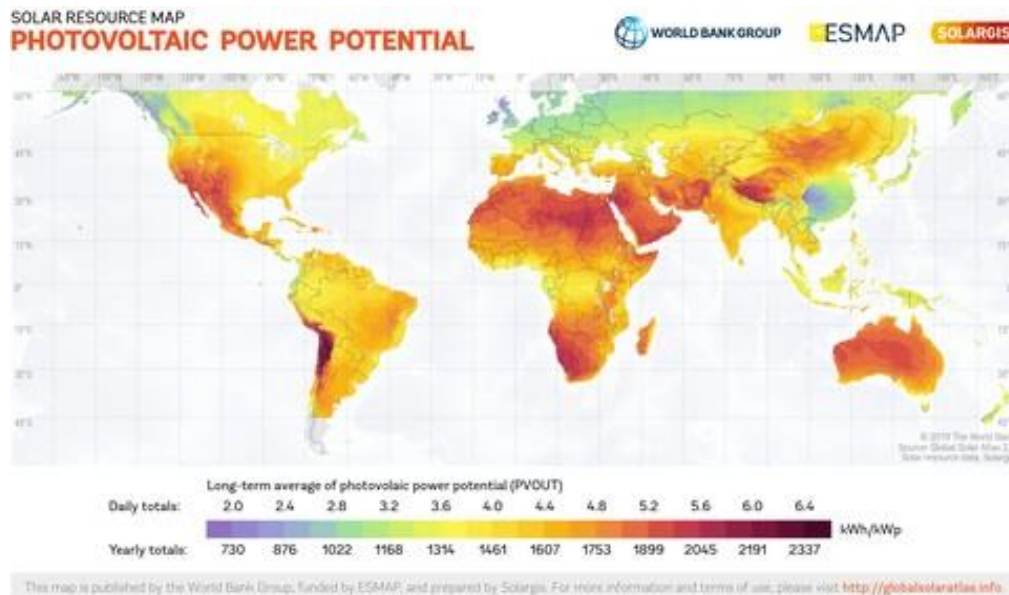


Fig. 1. Figure Caption

The top installers of 2022 included China, the United States, and India. Japan, Brazil, the Netherlands, France, Mexico and Germany were also among the top installers of 2022. The available solar PV capacity in Australia is now sufficient to force further than 15 percent of the nation’s electrical energy while Honduras, Italy, Spain, Germany and Greece can produce between 9 percent and 14 percent of their respective annual domestic electricity consumption.

**TABLE I
TABLE CAPTION**

Country	Generation
China	4.8
United States	4.8
Japan	9.9
India	5.1
Germany	10.7
Australia	14.2

Spain	11.5
South Korea	4.8
Italy	9.7
Brazil	3.9

Fig. 2. Figure Caption

Pros and cons

Pros:

- PV panels give clean – green energy. During electricity generation with PV panels there's no dangerous greenhouse gas emissions therefore solar PV is environmentally friendly.
- Solar energy is energy supplied by nature – it's therefore free and abundant!
- Solar energy can be made available nearly anywhere there is sun
- Solar energy is especially applicable for smart energy networks with distributed power generation – DPG is indeed the coming generation power network structure. Solar panels cost is presently on a fast reducing track and is anticipated to continue reducing for the coming times – accordingly solar PV panels has indeed a largely promising unborn both for provident viability and environmental sustainability.
- Photovoltaic panels, through photoelectric miracle, produce electricity in a direct electricity generation way
- Operating and conservation costs for PV panels are considered to be low, nearly negligible, compared to costs of other renewable energy systems
- PV panels have no mechanically moving corridor, except in cases of sun-tracking mechanical bases; accordingly they have far less breakages or bear lower conservation than other renewable energy systems (e.g. wind turbines)
- PV panels are completely silent, producing no noise at all; accordingly, they're a perfect result for civic areas and for domestic operations (see solar panels for home)
- Because solar energy coincides with energy requirements for cooling, PV panels can give an effective result to energy demand peaks – especially in hot summer months where energy demand is high.
- Though solar energy panels' prices have seen a drastic reduction in the once times, and are still falling, nevertheless, solar photovoltaic panels are one of major renewable energy systems that are promoted through government subvention backing (FITs, duty credit etc.); therefore fiscal incitement for PV panels make solar energy panels an seductive investment volition.
- Domestic solar panels are easy to install on rooftops or on the ground without any hindrance to domestic life.

Cons:

- As in all renewable energy sources, solar energy has intermittency issues; not shining at night but also during day there may be cloudy or stormy rainfall. Accordingly, intermittency and unpredictability of solar energy makes solar energy panels less dependable a result.
- Solar energy panels bear fresh outfit (inverters) to convert direct electricity (DC) to interspersing electricity (AC) in order to be used on the power network.
- For a nonstop force of electric power, especially for on-grid connections, Photovoltaic panels bear not only Inverters but also storehouse batteries; therefore adding the investment cost for PV panels vastly.
- In case of land-mounted PV panel installations, they bear fairly large areas for deployment; generally the land space is committed for this purpose for a period of 15- 20 times or indeed longer.
- Solar panels effectiveness situations are fairly low.
- Though PV panels have no considerable conservation or operating costs, they're fragile and can be damaged fairly fluently; fresh insurance costs are thus of ultimate significance to guard a PV investment.

IMPACT OF SOLAR PHOTOVOLTAIC TECHNOLOGIES

Solar photovoltaic (PV) technology has had a significant impact on the globe across colorful confines:

- Renewable Energy Transition Solar:* PV has played a pivotal part in the global transition towards renewable energy sources. It has surfaced as one of the swift-growing sources of electricity generation, contributing to reducing the reliance on fossil energies and mollifying climate change.
- Reduced Carbon Emissions:* By generating electricity from sun rather than burning fossil energies, solar PV helps to reduce greenhouse gas emissions, particularly carbon dioxide (CO₂). This reduction in emissions is vital for combating climate change and meeting transnational climate targets outlined in agreements like the Paris Agreement.
- Energy Access and Security:* Solar PV has bettered energy access in numerous corridor of the world, especially in remote or out-grid areas where traditional grid structure is absent or shy. It enhances energy security by diversifying the energy blend and reducing reliance on imported reactionary energies, therefore making countries less vulnerable to force dislocations and price oscillations.
- profitable Benefits:* The solar PV assiduity has created jobs encyclopedically, from manufacturing and installation to conservation and exploration. As the technology has come more affordable and wide, it has also led to cost savings for consumers and businesses through lower electricity bills and avoided costs associated with environmental and health impacts of conventional energy sources.

- e) *Technological Advancements:* The rapid-fire growth of the solar PV assiduity has prodded invention and technological advancements, leading to more effective solar panels, bettered energy storehouse results, and better integration with the grid. These advancements have farther driven down costs and increased the competitiveness of solar PV compared to conventional energy sources.
- f) *Environmental Benefits:* In addition to reducing carbon emigrations, solar PV has other environmental benefits similar as reducing air and water pollution associated with reactionary energy birth, transportation, and combustion. It also has a lower environmental footmark in terms of land use compared to some other renewable energy sources like bioenergy orhydropower.
- g) *Adaptability and adaption:* Solar PV systems can contribute to enhancing the adaptability of energy structure against extreme rainfall events and natural disasters. Distributed solar PV installations, including rooftop solar panels, can continue to induce electricity indeed if centralized power shops or transmission lines are damaged, helping communitiesto recover more snappily from dislocations.

ADVANCEMENTS IN SOLAR PHOTOVOLTAIC TECHNOLOGY AND THE FUTURE

Advancements in solar photovoltaic (PV) technologies have been significant, driven by ongoing exploration, development, and invention. Some notable advancements include

- a) *Increased effectiveness:* Experimenters continuously work on perfecting the effectiveness of solar PV cells, which refers to the chance of sun converted into electricity. Advancements in accoutrements wisdom, similar as the development of new semiconductor accoutrements and new cell designs like multi-junction and tandem cells, have led to advanced effectiveness situations. These advancements allow solar panels to induce more electricity from the same quantum of sun.
- b) *Perovskite Solar Cells:* Perovskite solar cells have surfaced as a promising volition to traditional silicon-grounded solar cells. Perovskite accoutrements offer high effectiveness, lowcost fabrication processes, and the eventuality for flexible and featherlight solar panels. Ongoing exploration aims to address stability issues and gauge up product for marketable deployment.
- c) *Tandem Solar Cells:* Tandem solar cells, which combine two or further different types of solar cell accoutrements to prisoner a broader range of the solar diapason, have demonstrated significantly advanced edge than single-junction cells. These tandems can correspond of combinationslike silicon/ perovskite or perovskite/ CIGS(bobby indium gallium selenide), enabling more effective application of sun.
- d) *Bifacial Solar Panels:* Bifacial solar panels can induce electricity from both the front and hinder sides of the panel, landing sun reflected from the ground or girding shells. This design increases energy yield, particularly in surroundings with high albedo, similar as snowy regions or areas with light-colored shells.
- e) *Thin- Film Solar Technologies:* Thin- film solar technologies, similar as cadmium telluride(CdTe) and bobby indium gallium selenide(CIGS) solar cells, offer advantages similar as inflexibility, featherlight, and implicit for low- cost product. exploration sweats concentrate on perfecting the effectiveness and stability of thin- film accoutrements to make them more competitive with traditional silicon-grounded solarcells.
- f) *Solar Cell Integration :* Integration of solar cells into structure accoutrements and everyday objects, known as buildingintegrated photovoltaics(BIPV) and integrated photovoltaic (IPV) systems, independently, is gaining traction. These technologies enable solar panels to blend seamlessly with architectural designs and structure, expanding the implicitoperations of solar PV.
- g) *Energy storehouse results:* Advancements in energy storehouse technologies, similar as lithium- ion batteries and flow batteries, complement solar PV systems by enabling energy storehouse for use during ages of low sun or high electricity demand. Coupling solar PV with energy storehouseenhances grid stability, improves trustability, and facilitates advanced situations of renewable energy penetration.
- h) *Smart Grid Integration and Monitoring:* Smart grid technologies and advanced monitoring systems allow for better integration of solar PV into the electricity grid. Real- time monitoring, prophetic analytics, and grid operation tools optimize the operation and performance of solar PV systems, perfecting grid stability and easing the effective integration of renewable energy sources.

HOW SOLAR PHOTOVOLTAICS HELPS IN FUTURE

Solar photovoltaic (PV) technologies play a pivotal part in shaping a more sustainable and flexible future in several ways

- a) *mollifying Climate Change:* Solar PV generates electricity without emitting hothouse feasts, helping to alleviate climate change by reducing reliance on fossil energies. As countries transition to low- carbon energy sources, solar PV will contribute to lowering carbon emigrations and meeting transnational climate targets.
- b) *Renewable Energy Transition:* Solar PV is a crucial motorist of the global transition towards renewable energy sources. Its scalability, affordability, and wide vacuity make it a feasible volition to traditional fossil energies. As solar PV deployment continues to grow, it'll contribute to diversifying the energy blend and reducing dependence on finite and contaminating coffers.
- c) *Energy Access and Equity:* Solar PV enables access to clean and affordable electricity, particularly in remote or offgrid areas where traditional grid structure is lacking. By furnishing decentralized energy results, solar PV contributes to bridging the energy access gap and promoting social equity, empowering communities and individualities with dependable power sources for lighting, heating, cuisine, and productive uses.
- d) *Economic Growth and Job Creation:* The solar PV assiduity creates jobs and stimulates profitable growth across the value chain, from manufacturing and installation to conservation and exploration. As the solar request expands, it generates employment openings in different sectors, fosters invention, and attracts investments, contributing to sustainabledevelopment and substance.
- e) *Flexible structure:* Solar PV systems enhance the adaptability of energy structure against dislocations and disasters. Distributed solar installations, coupled with energy storehouse technologies, give provisory power during grid outages, natural disasters, or extremities, icing durability of essential services and perfecting community adaptability.

- f) *Decentralized Energy Generation:* Solar PV promotes decentralized energy generation, empowering individualities, businesses, and communities to produce their own electricity. Distributed solar installations, similar as rooftop solar panels, reduce transmission losses, enhance grid stability, and promote energy independence, fostering a more flexible and popular energy system.
- g) *Technological Innovation:* Continued invention in solar PV technologies drives effectiveness advancements, cost reductions, and new operations, expanding the eventuality of solar energy across colorful sectors. Advancements in accoutrements wisdom, energy storehouse, and smart grid integration further enhance the performance and capabilities of solar PV systems, making them more protean and adaptable to different surroundings and requirements.
- h) *Environmental Benefits:* Solar PV offers multitudinous environmental benefits, including reducing air and water pollution, minimizing niche dislocation, and conserving natural coffers. By employing sun to induce electricity, solar PV mitigates the environmental impacts associated with conventional energy sources, securing ecosystems, biodiversity, and public health.

ACKNOWLEDGEMENT

Acknowledgment for solar photovoltaic (PV) technologies I would like to admit the inestimable benefactions of experimenters, masterminds, originators, policymakers, and assiduity stakeholders who have devoted their moxie, coffers, and sweats to advancing solar photovoltaic (PV) technologies.

Their collaborative commitment to developing and planting solar PV results has converted the global energy geography, paving the way for a more sustainable, flexible, and indifferent future. Also, recognition is due to the communities and individualities who have embraced solar PV, whether through installing rooftop solar panels, investing in mileage-scale solar systems, or championing for programs that support renewable energy relinquishment. Their enthusiasm, engagement, and support have been necessary in driving the wide relinquishment and acceptance of solar PV as a clean, dependable, and cost-effective energy source.

likewise, I admit the pioneering work of scientists and originators who have pushed the boundaries of solar PV exploration and development, exploring new accoutrements, infrastructures, and operations to enhance the performance, effectiveness, and affordability of solar PV technologies. Their groundbreaking discoveries and technological advancements continue to fuel progress and invention in the field, unleashing new possibilities and openings for solar energy application.

Incipiently, I extend appreciation to associations, governments, and institutions that have demonstrated leadership and commitment to promoting solar PV deployment, fostering collaboration, and creating enabling surroundings for renewable energy relinquishment. Through their programs, impulses, and investments, they have played a vital part in accelerating the transition to a sustainable, low-carbon energy future powered by solar photovoltaic technologies. Together, these collaborative sweats and collaborations have deposited solar PV as a foundation of the global energy transition, offering a pathway towards a cleaner, greener, and more prosperous world for present and unborn generations.

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