

## SOLAR SYSTEM: FUNDAMENTAL UNDERSTANDING AND ITS GLORIOUS EXPANSION TO MEET THE GLOBAL ENERGY DEMAND

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### ABSTRACT

The objective of this review was to share the general information to the community. The research approach involved searching, critical reviewing and analyzing the primary and secondary sources related to the topic. Solar energy is a valuable and eco-friendly technology that serves as a major renewable and green energy source. It plays a crucial role in promoting sustainable development by providing a significant daily energy supply, making it an attractive option for generating electricity. The current advancements in concentrated solar power (CSP) and solar photovoltaic (PV) techniques focus to level up our increasing energy demands. Consequently, the global adoption of solar energy supports the energy sector and creates employment opportunities, contributing to overall development.

**Keywords:** Solar system, PV technique, Glorious expansion, Clean energy.

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### INTRODUCTION

In recent years, there has been a growing demand for cleaner energy resources. As a result, decision-makers worldwide have prioritized renewable sources as part of long-term strategies. This shift away from traditional energy sources towards alternative technologies is essential to minimize reliance on the fossil fuels and focus on sustainable energy sources [1, 2].

Recognizing the need for global action, the United Nations adopted the sustainable development goals (SDGs) in 2015. These SDGs intend to reduce poverty, protect our environment, and assuring global prosperity

and peace by 2030. Achieving these goals requires a balanced approach that considers economic, social, and environmental sustainability [3].

Energy is a fundamental requirement for human communities to survive and thrive. As our civilization progresses, the demand for energy continues to grow. This demand has been further amplified by population growth and technological advancements in recent decades. Therefore, it is crucial to rely on green technology to meet our energy needs while also addressing the challenges posed by climate change [4-6].

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Although fossil fuels currently dominate the global energy system and will remain a significant source of energy in the near future, renewable energy sources must play a crucial role in the world's energy supply. The transition towards more sustainable energy sources is already underway [7-8]. While fossil fuel generation has attained its climax, solar energy is assumed to take the lead in energy generation in the coming years. It is estimated that by 2050, solar energy will account for 48% of global energy generation due to economic and industrial growth [9-10]. Solar energy technology has various advantages, including its renewable and clean nature, abundance, lower costs, minimal maintenance, and positive impact on the environment. This paper aims to emphasize the various applications of solar energy for sustainable development, making it valuable to researchers, engineers, and consumers alike. Its primary objective is to raise public awareness and promote the use of solar energy in everyday life.

#### **METHODS**

The chosen research approach involves searching, critical reviewing and analyzing the primary and secondary sources related to the topic. These sources encompass international law, journals, various websites, policy papers and textbooks. The research primarily relies on existing literature. The findings are based on thorough examination and logical interpretation of these gathered material. The analysis employs an integrative review process that incorporates various sources obtained from different websites through Google [11].

#### **TAXONOMY OF SOLAR ENERGY**

The taxonomy of solar energy applications can be divided into two categories: (i) Photovoltaics (PVs) and (ii) Concentrated Solar Power (CSP). Photovoltaic systems directly transform sunlight into electricity using solar cells made from semiconductor materials. These materials have

characteristics derived from atoms with four electrons in their external orbit. On the other hand, Concentrated Solar Power (CSP) captures and concentrates solar rays using mirrors. These rays heat a fluid, producing steam that powers turbines to generate electricity. The discovery of photovoltaic (PV) effect occurred in 1893. After years of massive research and development, solar energy technology has emerged into two main applications: 1. solar thermal and, 2. solar PV. The PV systems harness the energy from the Sun and convert it into electricity through the use of solar panels [12].

#### **DISCOVERY OF PHOTOVOLTAIC (PV) EFFECT**

Solar energy can be classified into two groups based on generation and availability. The first group consists of renewable sources like wind energy, biomass and wood energy, geothermal energy, tidal energy, and ocean energy [13]. The second group includes non-renewable sources such as coal, petroleum, and natural gas.

The PV system is based on photovoltaic (PV) effect, introduced by Alexandre Edmond Becquerel in 1839 [14, 15]. It involves a PV module composed of solar cells made from semiconductor materials. When solar radiation, in the form of photons, strikes the semiconductor material, it releases an electron from its atomic bond, generating an electric current. Commonly used materials for solar cells include monocrystalline silicon, polycrystalline silicon, amorphous silicon, copper indium gallium selenide and cadmium telluride [16]. More efficient materials, such as Light Sensitive Nanoparticles (LSN) and gallium arsenide, have been developed, surpassing the efficiency of traditional silicon-based solar cells [17, 18].

#### **THE CORE OF THE SOLAR PANEL**

Solar panels consist of 36 to 96 silicon cells staged in a straight line and connected in a loop. This setup allows them to generate

anywhere from 100 - 450 watts of power. Each cell, made of crystalline silicon, conducts current through tiny silver wires that connect to larger bus bars, eventually leading to panel's junction box [19]. Both the fingers and bus bars use silver and copper metals. To protect the cells, they are sandwiched in bilayers of ethylene vinyl acetate (EVA) foil and stealth with tempered glass on the top side and a PVF (polyvinyl fluoride) covering on the bottom side. This complex sandwich-like arrangement not only provides excellent protection from environment but also enhances structural stability, thanks to the tempered glass. Additionally, the panels have an outlets from aluminum channel frame for added stiffness, and the junction box connects to external/outside circuits [20].

PV cells, which are semiconductor diodes, convert sunlight into direct current electricity. Each PV cell produces a low voltage of 0.5 V at a high current of around 3 A. The PV modules is made up of multiple PV cells connected in series, with bypass diodes utilized to generate redundancy and additional electricity paths.

Commercial PV panels typically have a peak power ranging from 50 to 360 W, and in some cases, even up to 405 W.

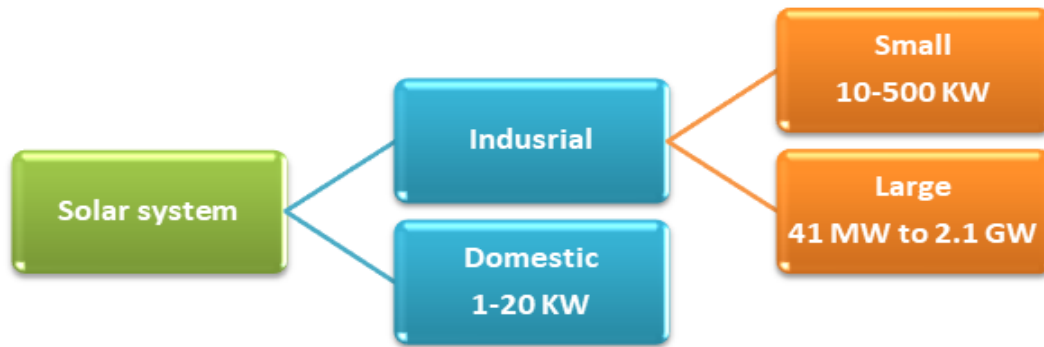
Solar cell technologies can be grouped into three generations: 1. First-generation - solar cells are based on crystalline Si wafers. 2. Second-generation - solar cells employ thin film technology, which includes Amorphous Silicon, Copper Indium Gallium Di-Selenide, Cadmium Telluride Copper Zinc Tin Sulphide, Gallium-Arsenide, and Indium Gallium Phosphorus.

3. Third-generation - solar cells encompass Perovskite solar cells, CZTS solar cells, Dye-sensitized solar cells, Quantum Dot solar cells, and Organic solar cells [21-24]. The efficiency of a solar panel is defined as the electrical energy generated divided by the total incident solar energy. Over the years,

the conversion efficiency of marketed panels has increased significantly. In 2000, it was around 16%, but today it stands at 24%. Even higher efficiencies have been achieved in research laboratories. The average daily solar irradiance worldwide varies from 4 to 7 kilowatt-hours (kWh/m<sup>2</sup>). This abundant solar energy is used for electricity generation in various applications such as water pumping, telecommunications, and lighting. Solar irradiance depends on factors like the time of day, weather conditions, geographical area, and position of the sun. The global market for PV panels has grown significantly, with the capability to generate clean energy on a global scale. It is predicted that PV-generated electricity would be the primary global energy source in the near future. In 2017, the installed capacity of solar PV energy almost doubled, with an additional 99.1 GWh being grid-connected. From 2010 to 2020, the installed capacity of PV technology increased from 40,334 MW to 709,674 MW. In the same timeframe, concentrated solar power (CSP) applications also grew, going from 1,266 MW to 6,479 MW [25-26].

China emerged as the world leader in solar power generation in 2017, accounting for approximately 32% of the global share. Japan and the USA followed closely behind. Notably, China installed one-half of the world's new solar power production capacity that year. Projections indicate that the global solar energy production capacity may reach 1,270.5 GW by the end of 2022, with solar power surpassing 1 TWh.

Traditionally, industries needed a large number of solar modules to generate high power, but land-mounted solar panels require significant space. To address this issue, PV panels have been installed on floating areas such as dams, reservoirs, lakes, and oceans. Many countries in Africa, Asia, and Japan have embraced this alternative due to limited land availability. The rapidly decreasing



**Figure 1:** Type and size of solar systems.

prices of solar energy are due to advancements in solar technologies. Additionally, the solar PV industry has played a crucial role in creating over 3 million jobs worldwide, making it a frontrunner in the renewable energy sector [27-30].

#### **COMPONENT OF SOLAR SYSTEMS**

The main components of a solar power system or solar panel kit are: 1. solar panels, 2. inverters, 3. mounting rack, and 4. batteries. Solar panels are planted on the roof-top of a household to capture energy from the sun. They convert sunlight into Direct Current electricity, which is then sent to the inverter. A cluster of solar panels working together is called a solar array. The solar panels have movable parts and typically last 20-25 years with a warranty [31, 32]. In Australia, a common size for solar panels is a 6.6kW solar system. For example, with 370-watt solar panels, this system would consist of 18 panels. If the panels receive 8 hours of sunlight per day, the system could be expected to produce around 26kWh of electricity daily.

The inverter, often considered as the brain of whole solar system, plays a crucial role. Its function is to regulate the energy received from the solar array from DC electricity to Alternating Current electricity (AC electricity), which can then be used to power household appliances and meet electricity needs. Unlike solar panels, inverters have moving components, and their location and

maintenance can affect their efficiency and lifespan, which is typically around 10-15 years.

Inverters are essential in PV systems as they control the power produced from solar panels and effectively transform the electrical current for injection into the grid supply. There are three types of PV inverters based on power rating including: centralized inverters, string inverters, and microinverters [33, 34].

Racking refers to the structure that securely holds the solar panels in fixed position. Racking systems include mounting rails and flashings to grip the rails to rooftops or ground mounts. There are two common categories of domestic solar systems: roof mount racking and ground mount racking. Firstly, the roof mounts use the building's rafters to hold the heavy weight of solar panels. For roof-mounted systems, holes are made into the rafters and the flashings are fixed in position. If the rafters are not open under the edge of the roof, use a stud finder to trace them or measure their position from inside the attic. This type of roof mount systems are considered a standard option for most domestic solar installations because of their convenience and cost effectiveness. Installing panels on the roof-top saves valuable space, which is important if you have limited space and can not be suitable for ground mounting.

A ground mount rack is a stand-alone support frame made of metal pipes firmly footed into

concrete on the ground. This ground mounts utilize much time and more money to install because its practically building a new structure to hold the solar setup. However, ground mounts permits much more flexibility with the orientation of the array. The panels can be pointed out directly toward the equator and tilted at the optimal angle to maximize the system's efficiency. Contrary to roof mounts, ground mounts permit for easier access for desired cleaning and maintenance. It is not needed to climb on the roof to clean the dust off the front of solar panels with a ground mount. The commercial and domestic properties are particularly well-suited for ground mount systems, as they often have ample space to build an array that fully utilizes the capacity of their solar panels. Solar batteries are an optional component in a solar power system to use stored energy produced during the day for its use at night or during grid outages. A battery bank can store a large amount of energy, making it ideal for off-grid systems or hybrid setups combining solar with grid power. The types of solar batteries available include lead-acid, nickel-cadmium, lithium-ion, and flow batteries.

### **PV SYSTEM APPLICATIONS**

PV arrays have a lifespan of 30 years and come in different shades, which depend on the material used in their production. Solar energy offers several advantages over other renewable sources, including: 1. Easy

installation of solar equipment, 2. Ability to use solar power anywhere, 3. Longer lifespan for solar equipment compared to wind and hydro, which require equipment replacement, and 4. Similar expected output for solar energy.

There are multiple cost-effective large-scale applications for a PV solar system including: 1. Water pumping, 2. Lighting, 3. Communications, 4. Refrigeration, 5. Generate electricity, and 6. Running home appliances [35].

### **CONCLUSION**

After installation, solar systems provide a lifetime of production. They have become a significant source of renewable energy, offering various applications for both domestic and industrial purposes. The global impact of solar systems is evident in their contribution to the growth of manufacturing industries and the creation of numerous job opportunities.

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