Chapter

Solar Photovoltaic Energy System

Sanusi Yekinni, Ibrahim Asiata, Oyeshola Hakeem and Lawal Mubarak

Abstract

Solar Energy in term of Photovoltaic (PV) solar cells as one of the promising renewable energy sources which has the potential to meet the future energy demand. The importance of developing different types of renewable energy sources which include solar, wind, hydro, biomass, geothermal and hydrogen gas to supply the energy for sustainable development will present. The different types and the principle of the PV cells fully discussed. The potential applications and futures prospect of the PV solar energy system in the various area of life will be considered and discussed.

Keywords: renewable, energy, photovoltaic, solar energy, solar cells

1. Introduction

In recent years, the world has experienced a number of health pandemics [1]. A pandemic, according to the World Health Organization (WHO), is the spread of a new illness that negatively affects a sizable section of the global population [2]. However, the most recent pandemic known as the COVID-19 has given grave consequences to the whole world. Due to the dissemination of COVID-19, a variety of events that had an impact on how energy was used were seen from the perspective of the energy industry [3, 4]. Due to the release of greenhouse gases, fossil fuels including coal, oil, and natural gas have been shown to have a negative impact on both the environment and human health (GHGs). Therefore, as long as the globe continues to rely on conventional fuel-powered economy, the ambition of achieving a cleaner environment will not be possible. The world will eventually look for alternate energy since present fuels are not sustainable. In order to revitalize the economy, create more jobs, and enable the countries that are using them to be energy independent, this situation could be resolved by the efficient and effective use of renewable energy sources, which have a prodigious potential to provide a great amount of energy that exceeds the global energy demand. The share of renewable energy in the world's power generation was 28% in 2020, and it is anticipated to increase to above 26% by 2020 [5]. **Figure 1** illustrates how renewable energy is produced from resources that are renewed naturally. It is a clean and sustainable energy from natural sources such as Sun, Wind, Water, Ocean and Earth natural activities [6]. Concerns about air pollution, public

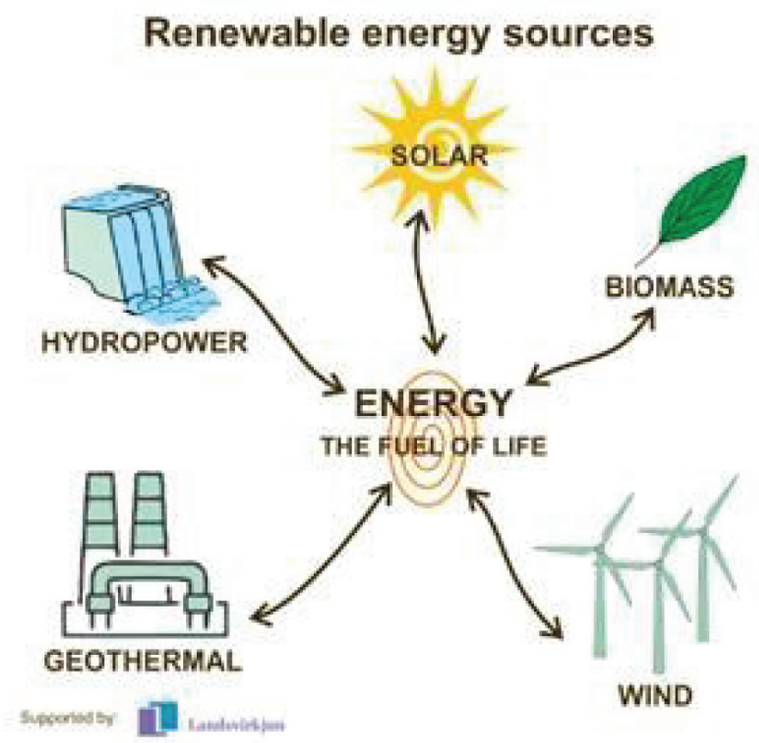

Figure 1.
Renewable energy sources.

pressure, and the desire to produce clean, livable, and egalitarian communities, among other things, all contributed to the sustained growth of government participation in 2020. In certain cases, the COVID-19 pandemic-induced global health and economic crisis has strengthened these activities, which have used a variety of objectives, policies, and actions to demonstrate their commitment to renewable energy: Around 25% of the urban population, or more than 1 billion people, resided in cities in 2020 that had either a renewable energy target or policy [7]. Since the 1990s, renewable energy technologies (RETs) have demonstrated the quickest growth rate among the various energy sources, maybe in spite of this tiny proportion (**Figures 2–5**) [9]. The focus of this chapter is to provide an adequate understanding about all the renewables, going through their share in world energy consumption, their importance, various technologies adapted to harness these renewable sources. Also an evaluation regarding the environmental impact, economics, and other social effects resulting from the use of the renewable energy systems is provided (**Table 1**).

1.1 Geothermal energy production

Geothermal energy is the residual heat developed from the formation of the earth billions of years ago as shown in **Figure 6**. The radioactive decay of potassium's radioactive isotopes causes phenomena known as radiogenic heat, which produces heat at a rate of around 3.5*109 W/kg of the element. Thorium produces 26.3*106 W/kg whereas uranium produces 96.7*106 W/kg. About half of the heat that is transferred from Earth's core to its surface is caused by this heat. Though there are pros and cons of geothermal energy (**Table 2**) [10]. There are various approaches employed by numerous people and institutions to classify the

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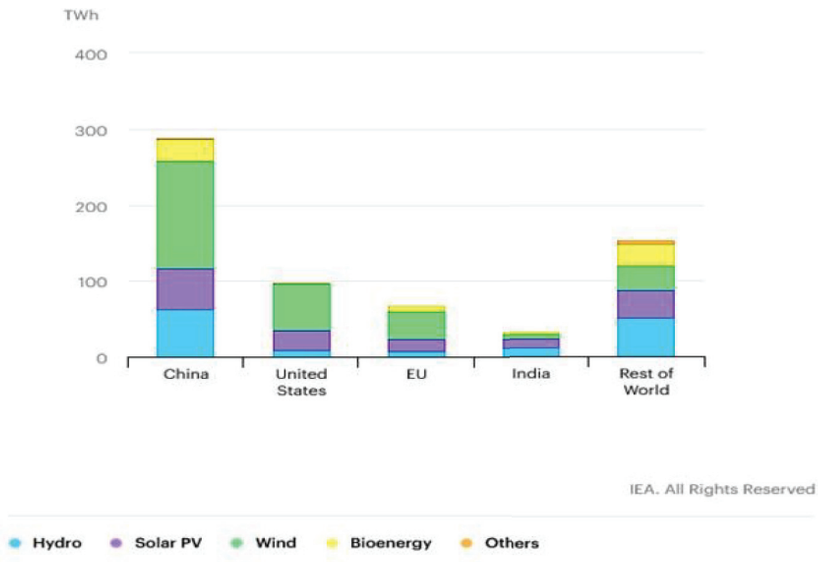


Figure 2.
Increase in renewable electricity production by technology, country, and region 2020–2021 [8].

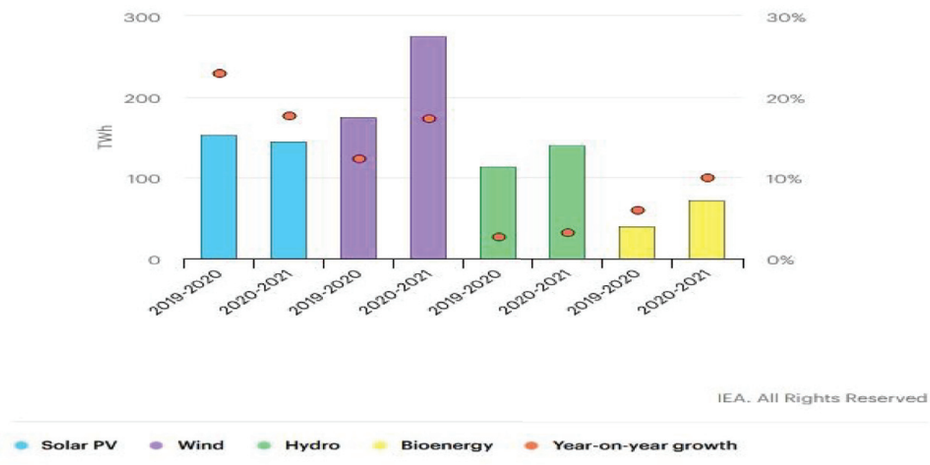


Figure 3.
Renewable electricity generation increase by technology, 2019–2020 and 2020–2021 [8].

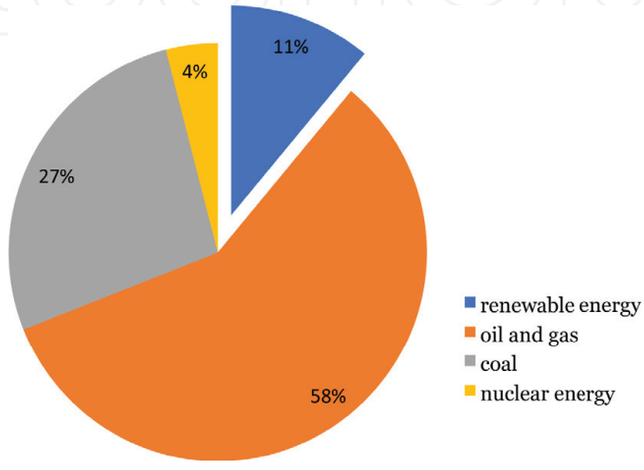


Figure 4.
World energy consumption for the year (2018).

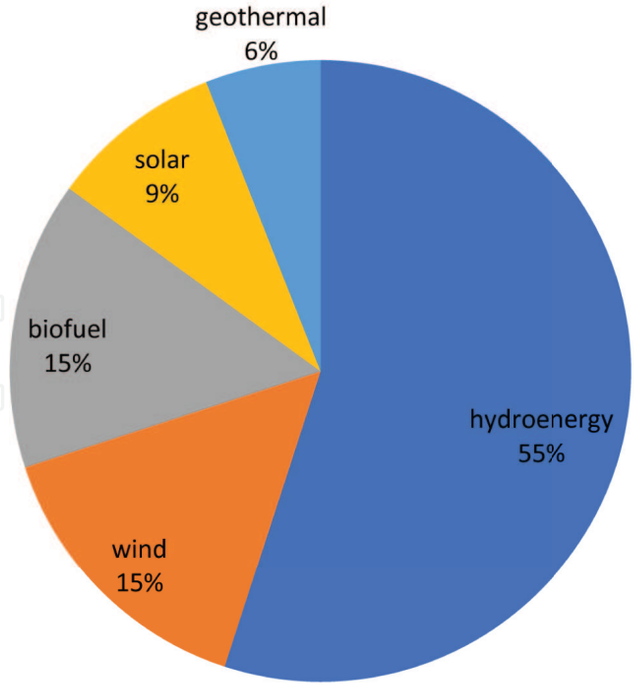


Figure 5.
Renewable energy consumption (%).

Source	Technology	Energy product
Bio-energy	domestic Combustion industrial Combustion Gasification (power and fuel production)	Heat (cooking, space heating) Process heat, steam, electricity Electricity, heat. Hydrocarbons H2
Wind energy	Sails	Movement
	Water pumping (turbines and mills)	power
	Onshore wind turbines	Electricity
	Offshore wind turbines	Electricity
Solar energy	Photovoltaic solar energy	Electricity
	Solar thermal electricity conversion	Heat, steam
	Low-temperature solar energy use	Electricity, Heat (water and space heating, cooking, doing) and cold
	Passive solar energy use Artificial photosynthesis	Heat, cold, light, ventilation H2 or hydrogen rich fuels
Geothermal energy	Geothermal conversion	Heat, steam, electricity
Hydro energy	Hydropower	Power, electricity
	Tidal energy conversion	Electricity
	Wave energy conversion	Electricity
	Current energy conversion	Electricity
Ocean thermal energy conversion	Heat, electricity	
	Salinity gradient / osmotic energy	Electricity

Table 1.
Classification of renewable production [10].

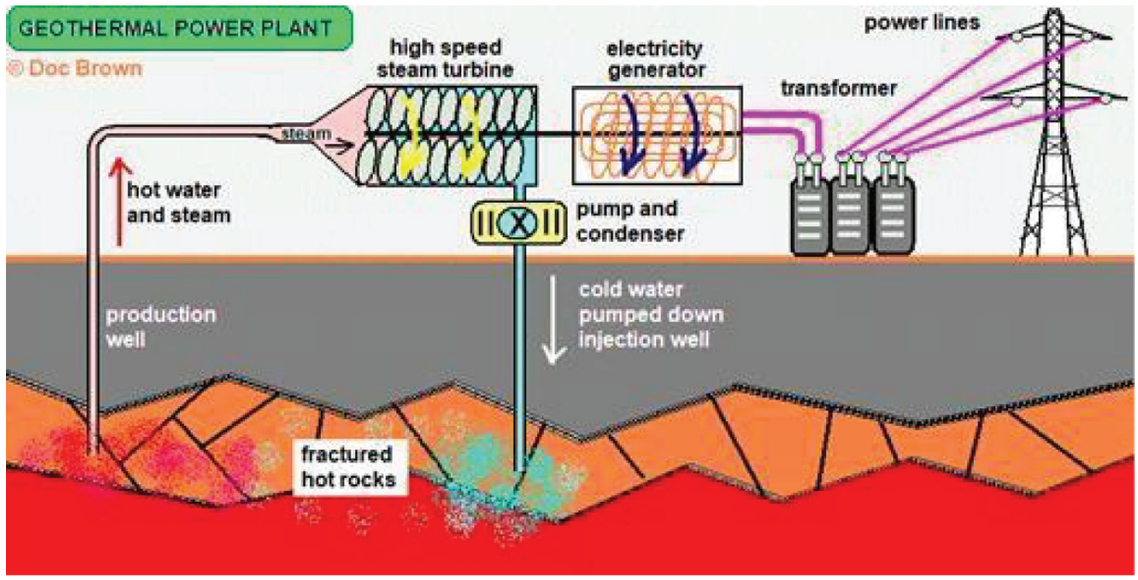


Figure 6.
Schematic diagram of geothermal power plant [11].

Pros	Cons
This energy source is more environmentally friendly than conventional fuel sources.	The largest single disadvantage of geothermal energy is that it is location specific.
A source of renewable energy.	Gases are released into the atmosphere during digging.
The number of exploitable geothermal resources will increase with on-going research and development in the industry.	Geothermal energy runs the risk of triggering earthquakes.
A sustainable source of energy as its. Always available unlike wind and solar.	Expensive resource to tap into, with high upfront costs ranging from around $2–7 million for a plant with a 1 megawatt capacity.
A reliable source as its. Easier to predict the power output from a geothermal plant with a high degree of accuracy. No fuel is required.	Energy fluid needs to be pumped back into the underground reservoirs faster than it is depleted. Management is required to maintain sustainability.

Increase in exploration meaning that new technologies are being created to improve the energy process.

Table 2.
An overview of geothermal Pros and Cons [12].

geothermal resources, the classifications based on thermal and compositional features of the resources and geothermal fluid temperature/enthalpy are the most common [13].

1.1.1 Geothermal energy application

Geothermal energy is applicable in several energy production applications. For example:

i. Geothermal energy can be exploited to provide space cooling and refrigeration via the use of absorption cooling systems.

ii. The other methods of energy production include flash steam plants, dry steam plants, binary cycle plants, and hybrid power plants. It is also employed in district heating systems and for heat generation using heat pumps.

iii. Geothermal energy may be used to produce fuel by supplying the necessary energy to run a water electrolyzer to produce hydrogen and in the manufacture of ethanol.

1.2 Wind energy

The conversion of wind energy into more usable forms, often electricity, is known as wind power. In 2005, wind power facilities with a capacity of 58,982 megawatts provided less than 1% of the world's electricity. The production of wind energy increased by more than fourfold globally between 1999 and 2005. The majority of today's wind energy is produced as electricity by using an electrical generator to transform the movement of turbine blades into an electrical current. Wind energy is employed in windmills, a much older technology, to drive mechanical equipment that performs labor-intensive tasks like pumping water or crushing grain (**Figures 7** and **8**). Both large-scale wind farms and small-scale individual turbines can generate electricity for usage in remote regions using wind power. If wind energy is utilized to

Figure 7.
Wind energy generating system [14].

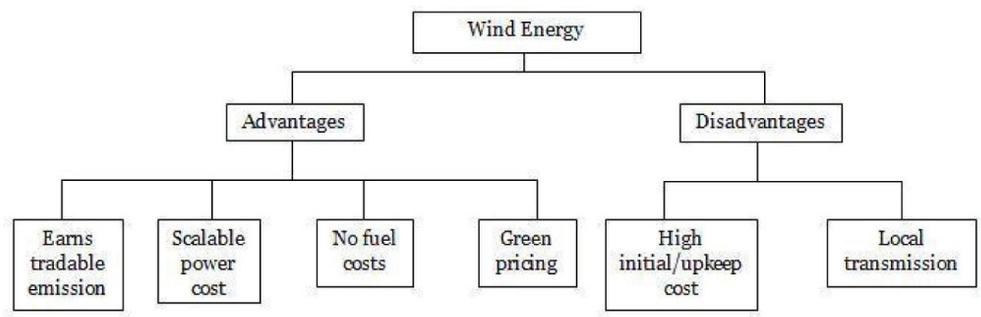


Figure 8.
Wind energy merits and demerits [15–18].

replace power produced from fossil fuels, it is abundant, renewable, widely available, clean, and reduces the greenhouse effect [14].

1.3 Hydro-energy

Hydro-energy is sourced from water activities. Water activities can be the water movement, tidal activities, ocean current and waves, physical and chemical reactions taking place in and on the water body. The water can be from surface water, ground water or an ocean. Hydro-energy can be in form of hydropower, tidal energy, wave energy, ocean salinity gradient exploitation and ocean thermal energy conversion (**Figure 9**). This hydropower is derived by using flowing water to drive turbines such that the output efficiency depends on the volume of water and the kinetic energy of the running water [20]. Tidal energy is sourced from ocean tides' movement which results from Earth-Moon rotation and the gravitational interaction with the sun [21]. Wave energy is harvested by using technology to capture the energy of waves caused by wind passing on the ocean surface and convert it to electrical energy. The energy produced by the variations in salinity between freshwater and seawater is known as salinity gradient energy. Ocean thermal energy conversion uses the temperature differential between deep cold water and warm surface water to produce power.

1.4 Bio-energy

Bio-energy is derived from the use of biomass. Biomass can be converted into different forms of bioenergy (**Figure 10**). Biomass is an organic, renewable source; it includes the entire successive species on the food chain, and also all biological waste [22].

1.5 Solar energy

Solar energy is simply energy from the sun; it is more or less the source of other forms of renewable energy, it involves capturing and harnessing the sun's energy and converting it into useful forms of energy. Solar energy is the most abundant source of electricity which in overtime its significant advancements would have

Figure 9.
Hydro energy generating system [19].

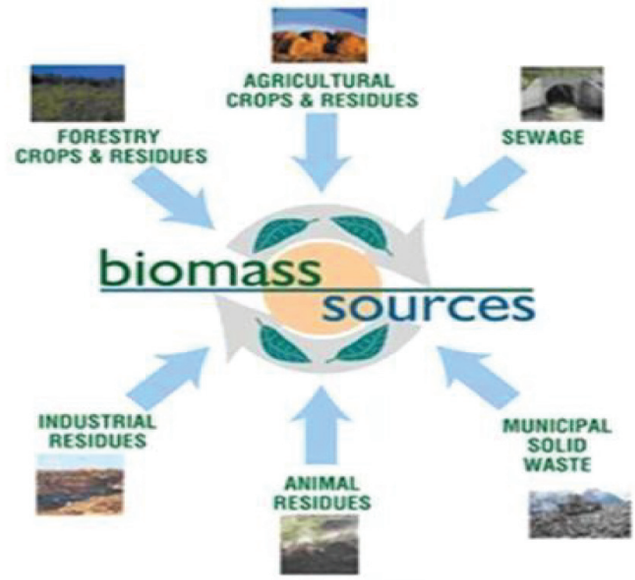


Figure 10.
Biomass energy system [22].

been produced [23–25]. There are different ways of harnessing solar energy like direct solar heating, solar radiation concentration, and solar cells.

1.5.1 PV solar panels

The photovoltaic effect is the basis for photovoltaic, which is the most direct method of converting solar energy into electricity (**Figure 11**). The appearance of an electric voltage between two electrodes connected to a solid or liquid system following the application of light to this system is known as the photovoltaic effect. Photovoltaic

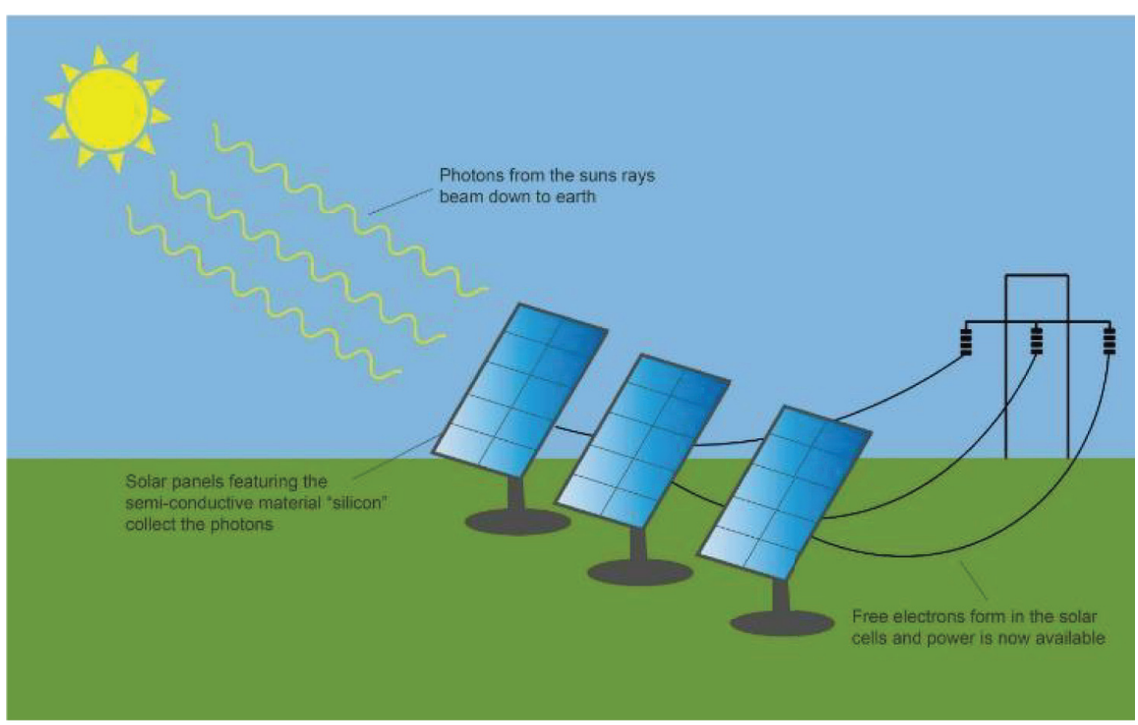
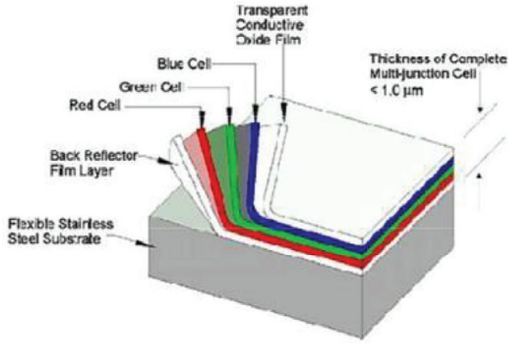


Figure 11.
Solar Electricity System [26].

of different types gratify diverse needs and tenacities. Assumed that sunlight can be used contrarily whether on Earth or in space points to the fact that location, itself, is a significant factor when it comes to selecting one of the types of photovoltaic over another. Moreover, classification by generation focuses on the materials and efficiency of the different types of PV [27, 28].

1.6 Different types of solar cells

Figure 12(**i-xxi**) [29, 30].



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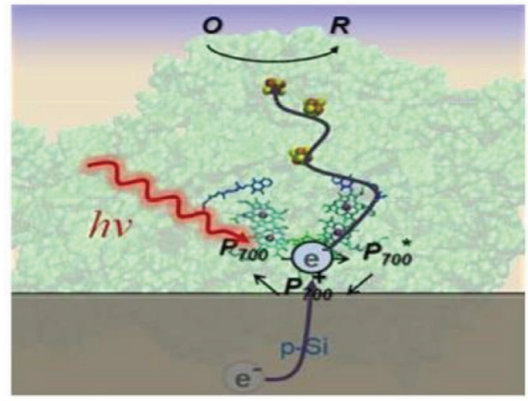

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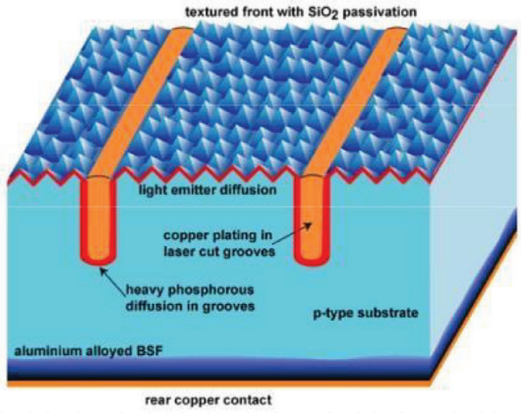

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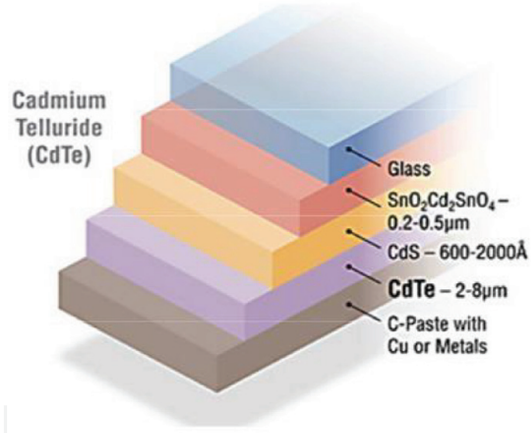

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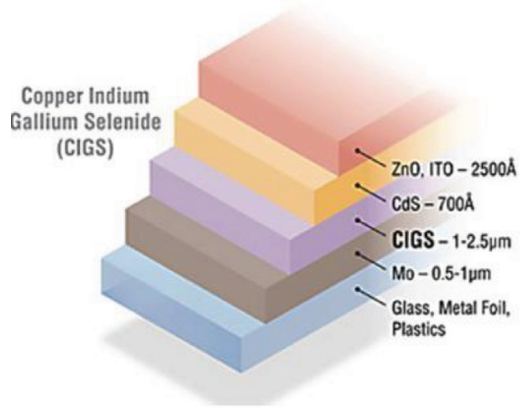

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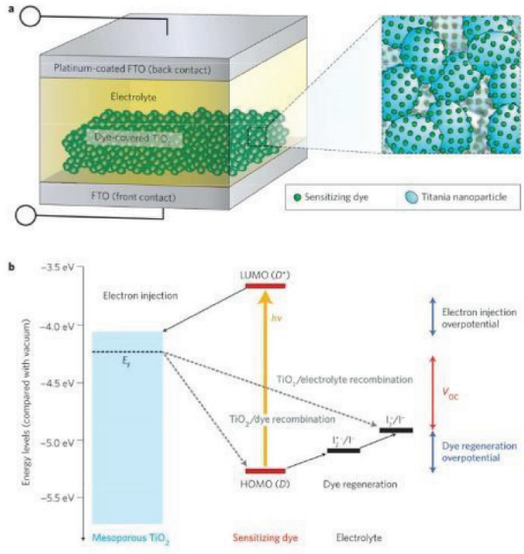

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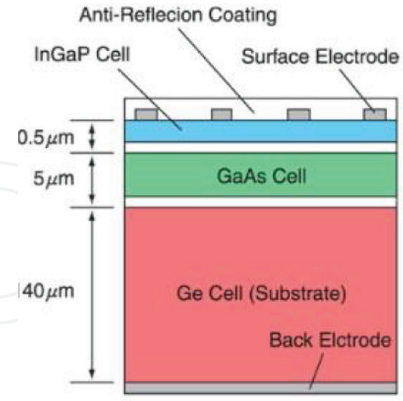

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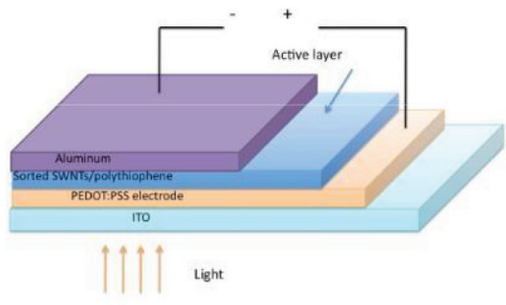

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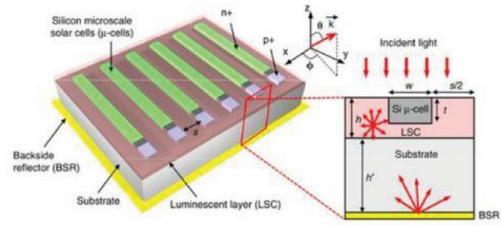

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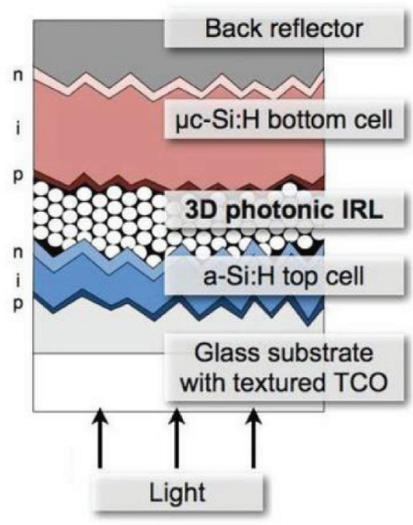

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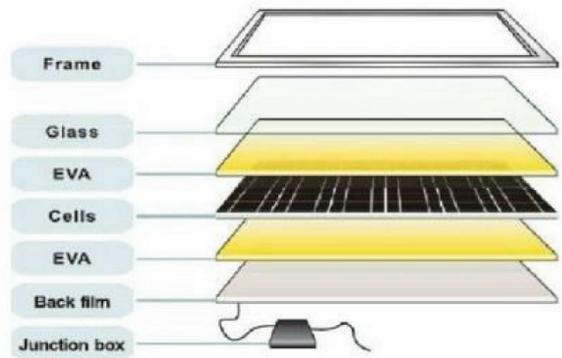

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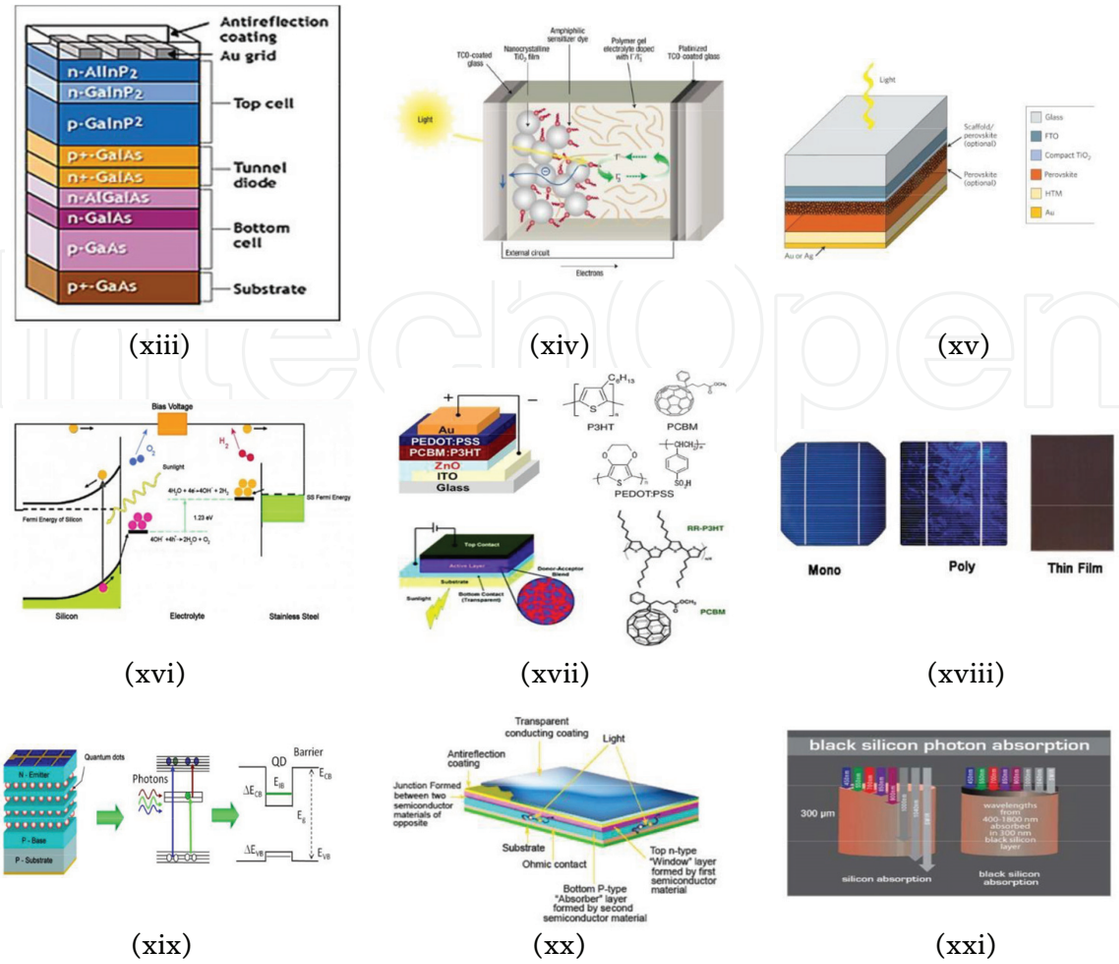

Figure 12.
Types of cells (Figures i to xxi). (i) Amorphous Silicon Solar Cell (A-Si); (ii) Biohybrid Solar Cell; (iii) Buried Contact Solar Cell; (iv) Cadmium Telluride Solar Cell (CdTe); (v) Concentrated PV cell (CVP and HCVP); (vi) Copper Indium Gallium Selenide Solar Cells (CI (G) S); (vii) Dye-Sensitized Solar Cell (DSSC); (viii) Gallium Arsenide Germanium Solar Cell (GaAs); (ix) Cell Hybrid Solar; (x) Luminescent Solar Concentrator Cell (LSC); (xi) Micromorph Cells (Tandem-Cell Using a-Si/µc-Si); (xii) Monocrystalline Solar Cell (Mono-Si); (xiii) Multijunction Solar Cell (MJ); (xiv) Nanocrystal Solar Cell; (xv) Perovskite Solar Cell; (xvi) Photoelectrochemical Cell (PEC); (xvii) Polymer Solar Cell (xviii) Polycrystalline Solar Cell (Multi-Si); (xix) Quantum Dot Solar Cell; (xx) Thin Film Solar Cell (TFSC); (xxi) Black Silicon Solar Cells.

1.7 Principle of PV solar cells

When light falls on a photovoltaic (PV) cell -also called solar cell device such light may be reflected, absorbed, or pass right through the cell.

2. Some applications of solar energy

1. Solar Power plants:

   Solar power plants: The sun's heat may boil water to produce steam that can be used to turn turbines. Solar power plants: The sun's heat may boil water to produce steam that can be used to turn turbines. To convert sunlight into

electricity solar panels, photoelectric technologies and thermoelectric technologies among other can be used.

2. Homes:

   Residential appliances can easily use electricity generated through solar power. Such as solar heating system and solar drying system

3. Commercial use:

   PV modules or any other kind of solar panel can be mounted on the roofs of different buildings so as to generate electricity.

4. Ventilation system:

   Solar energy is used for ventilation purposes at many places. It is beneficial to operate bathroom, floor, and ceiling fans in buildings to reduce moisture and odor, as well as in homes to remove heat from the kitchen.

5. Power pump:

   Solar power did not just help in improving ventilation system at various homes but can also help in circulating water in any building.

6. Swimming pools:

   In any season, swimming pools are a lot of fun for both adults and children. However, keeping the water heated in these pools throughout the cold months requires a lot of energy which many people can benefit from solar energy in this regard.

7. Solar Lighting:

   These lights are also known as day lighting, and work with help of solar power. These lights capture solar energy throughout the day and turn it into electricity to illuminate at night.

8. Solar Cars:

   It is an electrical vehicle which is recharged form solar energy or sunlight.

9. Remote applications:

   Remote structures are extensively utilizing solar energy for facilities like clinics, community centers, and schools.

3. The future of PV technology

The solar energy industry is starting to move accelerative quite quickly now. With more people opting for greener ways to power their homes, the market and the consequent solar photovoltaic investigation and improvement is increasing exponentially. The researchers are doing finding on cheaper and more eco-friendly solar cells.

4. Summary and conclusion

Solar energy is the sum of the heat and light that the sun produces. This energy moves from sun and reaches the earth where human tap and collects it through solar collectors and been converted into any desirable form of energy.

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