Solar Power

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Renewable Energy: Solar Power

Humans have long since been utilizing the energy potential of the sun with evidence dating back to as far as 7th century B.C. Early applications were primitive such as creating fires and lighting torches for ceremonial purposes. Since then, our understanding of solar energy has grown exponentially, allowing us to convert the sun's energy into electricity we can use to power our daily lives.

In 1839, the French scientist Edmond Becquerel discovered the ability to generate electricity caused by exposure to sunlight known as the photovoltaic effect. Becquerel found that an electrolytic cell made from two metal electrodes placed in an electrically conducting solution would generate electricity when exposed to sunlight. Off the backbone of Becquerel's discovery, many scientists began to study the photovoltaic effect finding that a solid material such as selenium had photoconductive potential.

In 1883, Charles Fritts created the first selenium solar cells, which were unsuccessful at generating enough electricity to power any devices but formed a proof of concept for the technology. Advancement of solar cell technology remained stagnant until 1954 when Daryl Chapin, Calvin Fuller, and Gerald Pearson created the silicon photovoltaic (PV) cell. The PV cell was the first iteration of solar technology with practical use that could reliably power an electric device. However, early iterations of silicon solar cells could only convert sunlight into electricity at a fraction of the rate capable today. Due to increased efficiency PV, solar cells have remained relevant and are far more applicable today.

Space programs were some of the earliest adopters of current solar technology, where small solar arrays were used to power radio equipment in outer space. The PV solar cell was highly successful at powering satellites; however, it failed to take off commercially in the 1950s and 1960s due to the high cost and low energy output of the technology. It became the accepted energy source for space applications and remains so today.

According to Solar Energy Industries Association (SEIA), solar power can be defined as the energy provided by the sun which is converted into thermal or electrical energy. Solar power is known for being a renewable, clean and the most abundant form of energy production in the world. With many applications, since powering up a calculator until providing energy for spacecrafts, solar power has shown to be a promising form of energy production which has been growing every year. In 2018 the solar energy market was evaluated at $52.5 billion and is predicted to hit $222.3 billion by 2026 (Hariharan and Prasad, 2019).

Solar power is obtained through photovoltaic (PV) cells that are comprised into multiple solar panels. These PV cells help to convert the sun's energy, emitted via rays of photons, into electricity. These structures are mainly made of silicon, which is a material with great capability of emitting electrons from its surface when struck by photons under the right circumstances, this process is known as photoelectric effect (Woodford 2019). The solar cells have two regions that were specially treated (doped) to allow the flow of electrons in different ways, they are called p-type and n-type. The first one, p-type, has a positive charge and contain electron holes, whereas the n-type is negatively charged. When both regions are put together, they form a junction causing a flow of electrons from the n-type layer to p-type layer, covering the holes, and creating a positive zone on the junction on n-type and a negative zone on p-type, generating an electric field ("How a Solar cell Works").

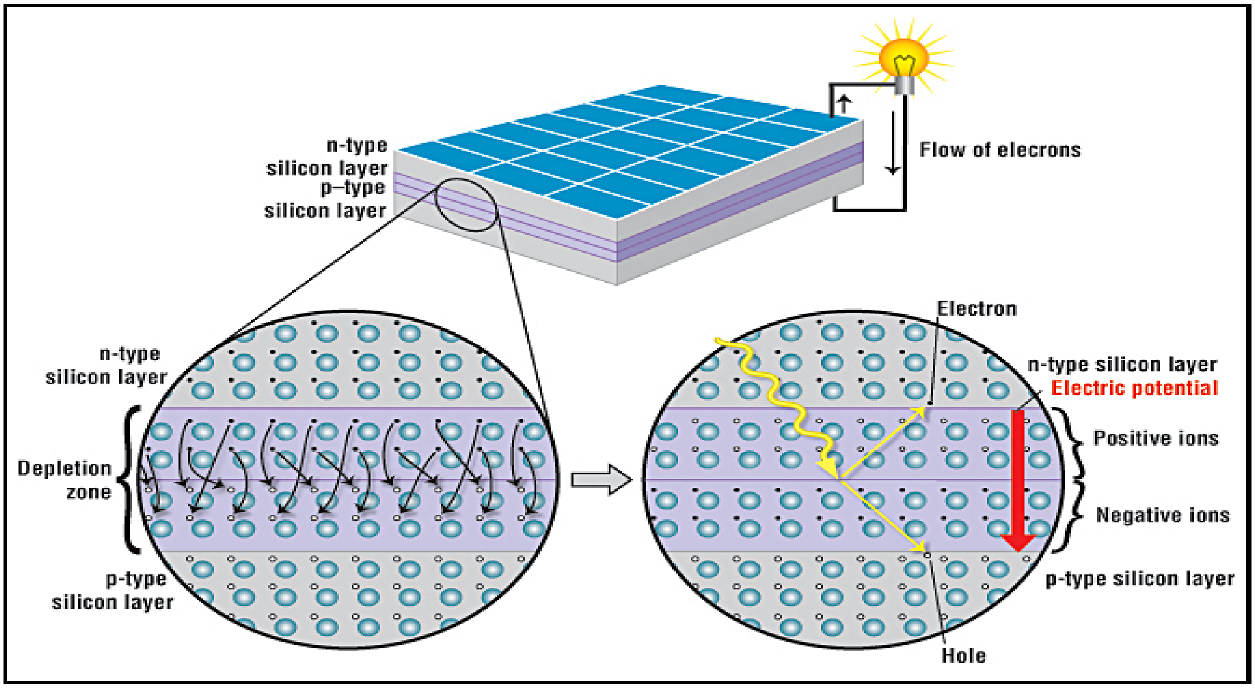

Figure 1. Anthony Fernandez, Schematic representation of a solar cell, showing the n-type and p-type layers

https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/archive-2013-2014/how-a-solar-cell-works.html

The photons from sunlight can pass through the n-type layer, and once it hits the depletion zone, in the electric field, photoelectric effect takes place. Photons give up their energy to the electrons in the silicon atom, knocking it off. The knocked electron goes to the n-type layer and the hole to the p-type. With both positive and negative charged zones in the solar cell it is possible to generate electric current by placing a metal wire on both layers.

However, the energy is not compatible with typical home/business energy installations, therefore it must be converted from direct current (DC) to alternating current (AC) through an inverter, which is usually located inside the home/business.

Although many focus primarily on the benefits of solar power, since it is valued so highly, there are some environmental issues that should be reviewed. One of the biggest issues is the amount of space they can take up, which can be detrimental to the land and ecological habitats.

With the exception of city usage for solar panels, many panels that are produced take up vast amounts of land so they can collect a substantial amount of energy from the sun, which can disrupt wildlife habitats. As well, the installation of these supersized panels have the potential to cause erosion and alter drainage channels, which can lead to irreversible impacts of land disruption. Aside from the large panels, the other issues are due to the production of these panels. In order to make solar panels, various rare/precious metals are needed which are not sustainable. As well, there must be a cooling system during the manufacturing process, which results in a high amount of water consumption; however, this water does not become contaminated and can be reused/returned to the environment. Not to mention that within the PV cells, there is a variety of chemicals used which could pose a threat in case there is a chemical leakage after processing or a chemical spillage at the manufacturing plant. Air quality is also a concern with every form of factory-based production of materials, but there should also be consideration that once made, no form of pollution will occur. Finally, there is no form of recycling for solar panels due to a lack of locations given that there are not enough non-operational solar panels that would make recycling them an economical advantage. As mentioned prior, solar panel composition is comprised of various chemicals and rare/precious metals which means that those metals are going to waste and the chemicals are going to damage the environment if the leak out, or react together with the rare metals over time.

These negative aspects should not discourage someone from turning to solar power as a form of renewable energy, as it is the cleanest form of renewable energy compared to other sources of energy such as geothermal or nuclear. It also can help save money in the long run since if one can produce more energy that is required, the energy service provider that is used will reimburse the user for the energy made; many compare this to the system paying itself off in the long run.

Not to mention that there would be no worry about running out of energy since the sun will always be around to provide heat and energy to Earth.

When it comes to using solar power, efficiency is a crucial aspect for determining which solar panel is the correct choice. Solar panels convert the sun's energy into usable electricity. A solar panel is considered efficient if it can convert the sun's energy at a low cost, while having a high output of electricity. Most solar panels have a 15%-22% efficiency rating, and the rating will vary depending on the manufacturer.

There are numerous things that contribute to solar panels efficiency. As fore-mentioned the efficiency of a solar panel is determined by the rate at which it can convert the suns energy into usable electricity. This conversion rate is affected by a multitude of factors such as material, wiring and reflection.

Material: There are three main types of solar panels based off their material, Monocrystalline, Polycrystalline and Thin-filmed solar panels. Each one varying in efficiency and effectiveness based off several pros and cons. The most popular type of material is silicone, and its efficiency is determined by the purity of the silicone being used. Monocrystalline solar cells have the highest efficiency rates, are very space efficient, and have the longest lasting lifetime. Polycrystalline solar panels are a cheaper alternative but are not as efficient and are less tolerant of heat. Finally, there is thin-filmed solar panels which are the cheapest. This material is mostly used in forms of mass production since they tend to have a low efficiency rating.

Wiring: The way that you wire your solar panels will have an impact on how effective it is producing electricity. There are multiple patterns that can be used in order to optimize the cells performance to help you save money on your electrical bill.

Reflection: In order for the solar panel to convert the suns energy into electricity it needs to minimize the amount of light it reflects. Absorbing more light means a more efficient panel that creates more usable electricity. Ultimately, saving you money over time.

There are a few factors that need to be considered when talking about the effectiveness of solar energy being stored. Once the suns energy is converted into usable electricity it can either be used immediately or stored in a battery for later use. Components such as capacity, power rating, depth of discharge and round trip-efficiency all contribute to a batteries ability to store power.

Capacity: The capacity of the battery is measured in kilowatt hours, and this is the total amount of electricity that a battery is capable of storing.

Power Rating: even though the battery may have a high capacity, it doesn’t mean it is going to be the most efficient. A power rating is the amount of electricity the battery is able to provide at a given moment; this is measured in kilowatts. These two factors go hand in hand because a battery with a high capacity and a low power rating would be able to provide enough electricity for a few small appliances in your home for a very long time. While a battery with a low capacity and a high-power rating would be able to provide electricity for your entire home, but for a very limited amount of time.

Depth of Discharge (DoD): When using your battery, if 100% of its charge is used then its useful life will be shortened. The depth of discharge is the amount of the batteries capacity that has been used. If a battery has a DoD of 80% then you should use 80% of its capacity before recharging it. In order to use more of the battery’s capacity, you will want a higher DoD.

Round Trip-Efficiency: Round trip-efficiency refers to the batteries economic value. Storing electricity in your battery requires energy, and using less energy makes it more efficient. If you get four kilowatts of usable electricity out of your battery with an initial input of five kilowatts from the solar panel then your battery has a round trip-efficiency of 80%. In order to have the most effective battery you will want a higher round trip-efficiency.

As mentioned above there are multiple factors that contribute to a batteries ability to effectively store power. There are many different types of batteries that can be used for the storage of solar energy. The most popular and effective ones are lead acid batteries. There are two electrodes in these batteries, one consisting of lead oxide and the other is pure lead. While the electrolyte in this battery is sulfuric acid. Lead acid batteries can be divided into two main groups:

Vented Lead Acid Batteries: these batteries have vents that are closed by small plugs. The plugs need to be removed in order to refill the distilled water lost during the chemical reaction. The specific gravity of the electrolyte can also be measured if these plugs are removed. The distilled water is required because these batteries release gases during the chemical reaction. These batteries require regular maintenance, which makes them a less popular choice for solar power compared to their counterpart.

Vented Regulated Lead Acid Batteries: This type of lead acid battery is very popular for solar power since they are regulated and are partially sealed to prevent evaporation of the electrolyte. This type of battery is able to recombine hydrogen and oxygen through an electrochemical process creating water. This process is considered 99% effective, meaning there is no water loss, and no maintenance needed.

The world is enthusiastic about the possible switch from fossil fuel-based energy systems towards a fully renewable clean energy production system. Solar energy is a big player in this possible future. However, green energy supporters tend to leave out important aspects of solar panel production, effectiveness, and waste disposal.

Solar Panels are most efficient in direct sunlight, where the energy from the sun is greatest. This means that areas with fewer rainy days will have an absolute advantage in energy production. Locations such as southern deserts are much better fitted for solar based energy systems than northern and temperate climates. This means that importing solar energy will be necessary. This could end up costing a lot of money for countries that do not get much sunlight, and the trade costs might result in a less than enthusiastic response from governments that must import their electricity,

Similarly, the fact that solar panels are not as effective in cloudy weather or at night is solar energy's greatest downfall: its intermittency. Our world energy needs are increasingly dependent on a large scale, consistent source of energy. We would not be able to operate the way we do if energy sources were intermittent. A sudden loss of electricity would be devastating.

Furthermore, while solar energy fairs much better than fossil fuels in terms of pollution and the production of greenhouse gases, it does have its environmental issues. Solar panels are made using silicon, an abundant material that must be purified. This purification process is not clean. A furnace hotter than 2000 degrees Celsius - powered by electricity - forces the oxygen out of the silicon molecules. This process is known as thermal reduction, and in order to reach the temperatures necessary, fossil fuel combustion is a must. In order to further purify the raw silicon, a chemical treatment involving hydrochloric acid and trichlorosilane is used. These chemicals are both extremely corrosive and harmful to the respiratory system.

In order for solar panels to be produced, expensive and rare minerals must be mined. These metals include praseodymium, dysprosium, and terbium. The extraction process is costly and environmentally unstable. Rare metals must be chemically separated since they do not occur naturally but are embedded in other rocks. The separation and extraction process are energy intensive and environmentally costly. Furthermore, the availability of rare metals may be too sparse to keep up with the increasing use of solar panels.

Canada currently invests roughly 3.3 billion dollars annually into fossil fuel companies in the form of subsidies, while the Canadian government only invests 200 million in renewable energy. However, a new solar farm in southeastern Alberta is projected to receive 49 million in funding. This farm will provide approximately 23 megawatts of electricity, enough to power 7,400 million homes, according to natural resources Canada.

There is worldwide support for an increase in solar energy, however in order for this increase to occur, Government Canada needs to divest in fossil fuels and begin investing more in renewables. While the technology for solar energy is making great strides, we are not yet able to power the entire country using what we have. There are loose ends that need to be fixed, such as the energy intensive rare earth mining, the dirty silicon purifying process, and the intermittency of solar energy.

The first recent advancement we will look into is see-through solar panels. Although partially see-through panels have been around for awhile, fully transparent ones were recently developed in 2017 by Michigan State University researchers. These work by absorbing infrared and UV light exclusively through the use of thin organic semiconductors and metals (Service). As of now they only achieve an efficiency of 5%, which is much lower than the standard 20-25%, but the researchers are sure they can eventually achieve at least 20% efficiency (Service). This would allow for buildings and homes, which account for 75% of electricity use in the U.S., to generate their own electricity. This would be especially useful in new skyscrapers and tall buildings to cut the rising energy demand as they have to put windows in regardless. The only downside to this would be in the instance of a broken window, due to solar panels containing toxic materials.

The next technology we will look into is multi-junction GaSB based solar cells. These are a relatively new type of photovoltaic cell which has reached an efficiency rating of 44.5% (Lumb *et. al*, 1). They achieve this efficiency by stacking cells in a mechanical process and using special optics which allows them to absorb 99% of the solar spectrum reaching the Earth's surface (Lumb *et. al*, 1). This is practically double the efficiency of normal cells and would therefore double the energy gained from the same amount of space used in the panel. This could be highly useful in places where the space is very limited. The downside to this invention however is that it is extremely expensive. It is not economically feasible yet, but it does show a proof of concept. It shows just how efficient solar panels can possibly be and gives incentive to produce future research improving cost and efficiency.

The final advancement we will look at is microgrids in conjunction with solar power generation. A microgrid is a local source of electricity that usually operates connected to the larger grid but can also disconnect and function autonomously (Ali & Shahnia, 1). Community microgrids are individual sources of small-scale energy generation all combining together to supply small neighbourhoods or towns. They would work by multiple citizens generating electricity and pooling it together to accommodate the rest. This system works incredibly well with solar panels as they are cheap and efficient especially in places closer to the equator. Normally it has one or several central storage units and bi-directional power electronic converters (Chandrasena *et. al*, 1). This technology in conjunction with solar power would help provide energy to the 1.2 billion people around the world without a convenient source of electricity. It is most needed in poorer regions, remote areas, and places where the energy demand is increasing too rapidly. Its main advantage is that it doesn't need any massive infrastructure such as power line towers and generating stations (power plants and hydroelectric dams). Compared to these generating sources solar panels in towns with no electricity would be much more feasible and cost effective. Another important advantage is that it can help to offset the carbon footprint of energy generation, which is done mainly by fossil fuel burning. If that demand was offset by solar (and other renewable energy) microgrids less pollution and greenhouse gasses would be produced by the power plants.

Overall, solar power has great potential to become a more prominent option as a form of energy production worldwide with advancements in technology leading to innovation in solar power production efficiency and reduced cost to convert to this form of renewable energy. Solar power is the cleanest, most abundant and most reliable form of renewable energy, therefore an increase in this method for electricity will play an important role in reducing the impact of non-renewable fuels, such as fossil fuel, leading to an ecologically friendly and sustained development of humanity.

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