یەکێتی ئەندازیارانی کوردستان
Kurdistan engineering union
اتحاد مهندسی کوردستان

Explanation, Definition and Types
Of
Solar Energy System

Prepared by: ***OMED HAMA NOORI***

Card No. : ***(6025)***

2023

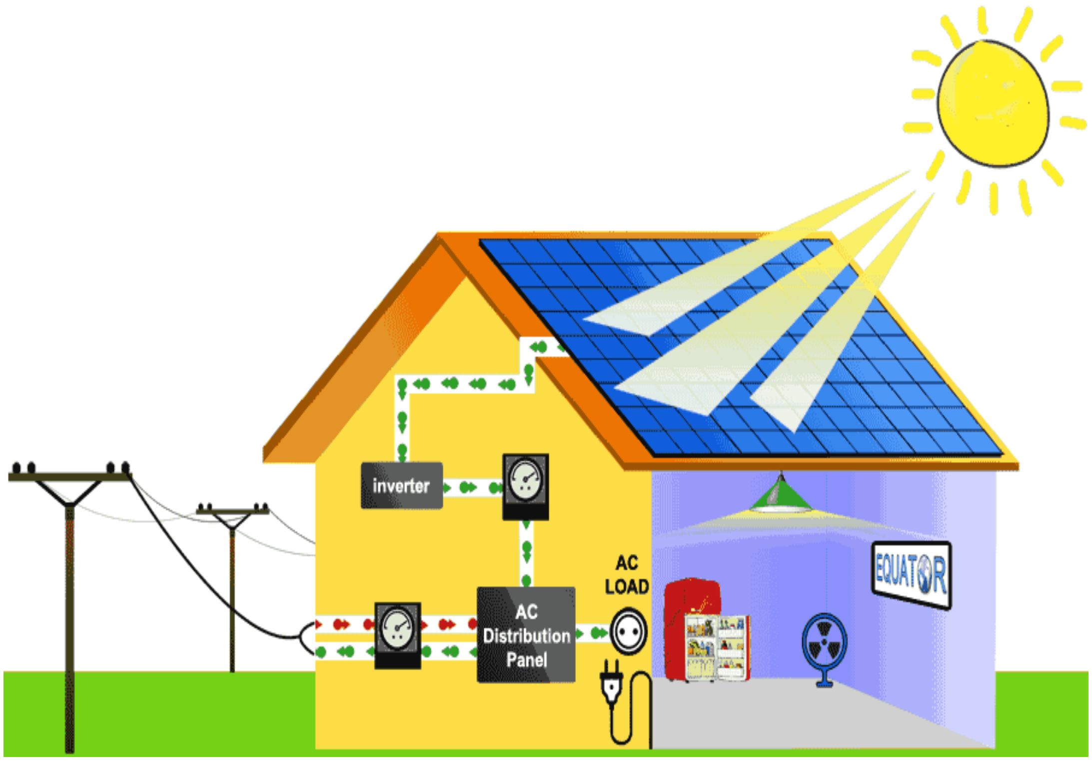
THR REPORT SUBMITTED TO THE KURDISTAN ENGINEERS UNION

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

Introduction:

Solar energy is a type of renewable energy which comes directly from the Sun. This energy drives the climate and weather and supports virtually all life on Earth.

Solar energy technologies harness the sun's energy for practical ends. These technologies date from the time of the early Greeks, Native Americans and Chinese, who warmed their buildings by orientating them toward the sun. Modern solar technologies provide heating, lighting, electricity and even flight.



Solar power is used synonymously with solar energy or more specifically to refer to the conversion of sunlight into electricity. This can be done either through the photovoltaic effect or by heating a transfer fluid to produce steam to run a generator.

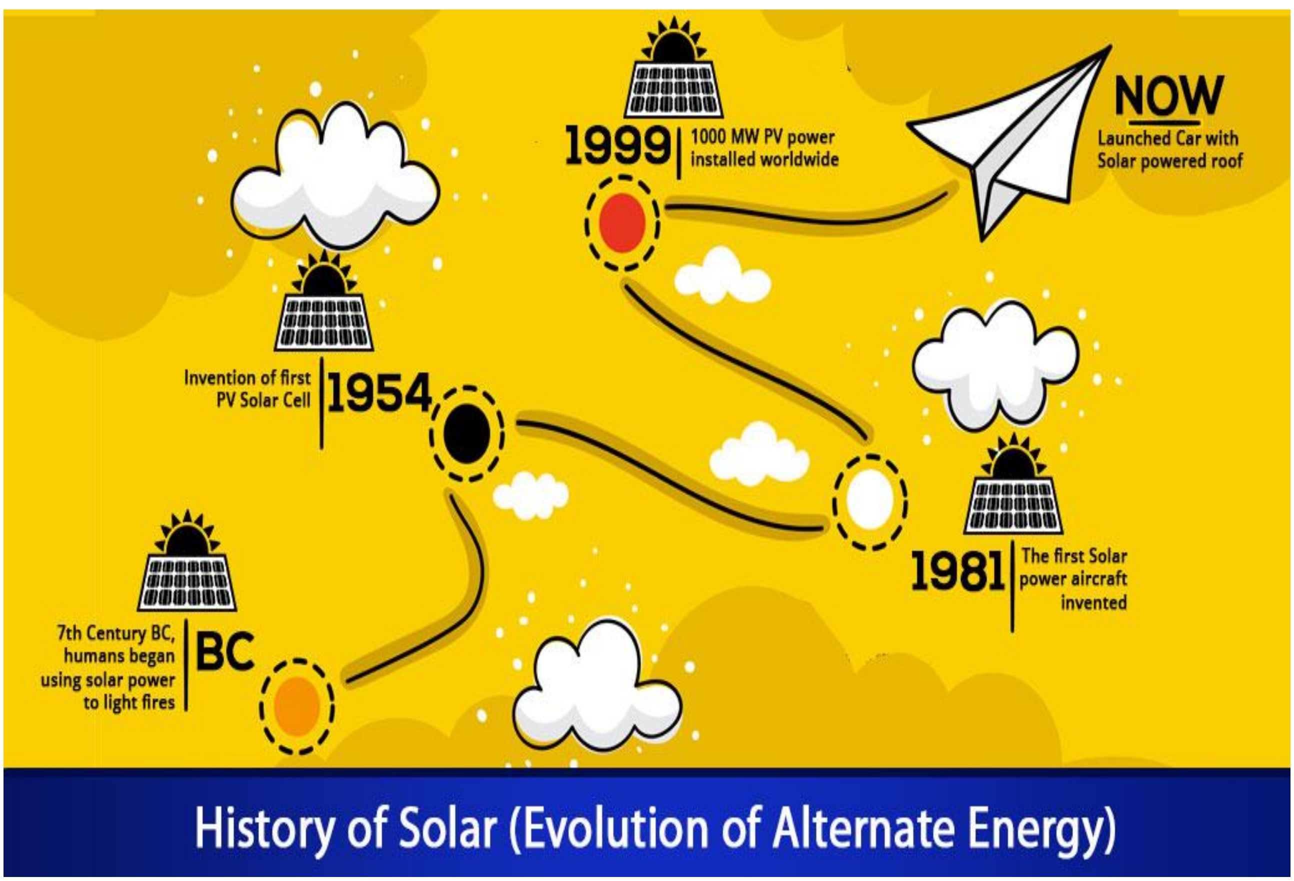
Solar energy is the energy obtained by capturing heat and light from the Sun. Energy from the Sun is referred to as solar energy. Technology has provided a number of ways to utilize this abundant resource. It is considered a green technology because it does not emit greenhouse gases. Solar energy is abundantly available and has been utilized since long both as electricity and as a source of heat.

History of Solar Energy:

The photovoltaic effect was first recognised in 1839 by French physicist Alexandre-Edmond Becquerel. However, it was not until 1883 that the first solar cell was built, by Charles Fritts, who coated the semiconductor selenium with an extremely thin layer of gold to form the junctions. The device was only around 1% efficient.

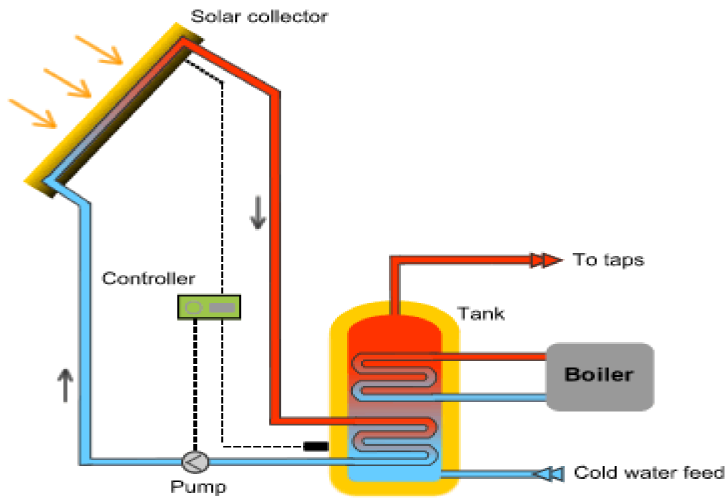
Russell Ohl, an American inventor on the payroll of Bell Laboratories, patented the world's first silicon solar cell in 1941. Ohl's invention led to the production of the first solar panel in 1954 by the same company. Solar panels found their first mainstream use in space satellites. For most people, the first solar panel in their life was probably embedded in their new calculator - circa the 1970s!

Today, solar panels and complete solar panel systems are used to power a wide variety of applications. Yes, solar panels in the form of solar cells are still being used in calculators. However, they are also being used to provide solar power to entire homes and commercial buildings, such as Google's headquarters in California.

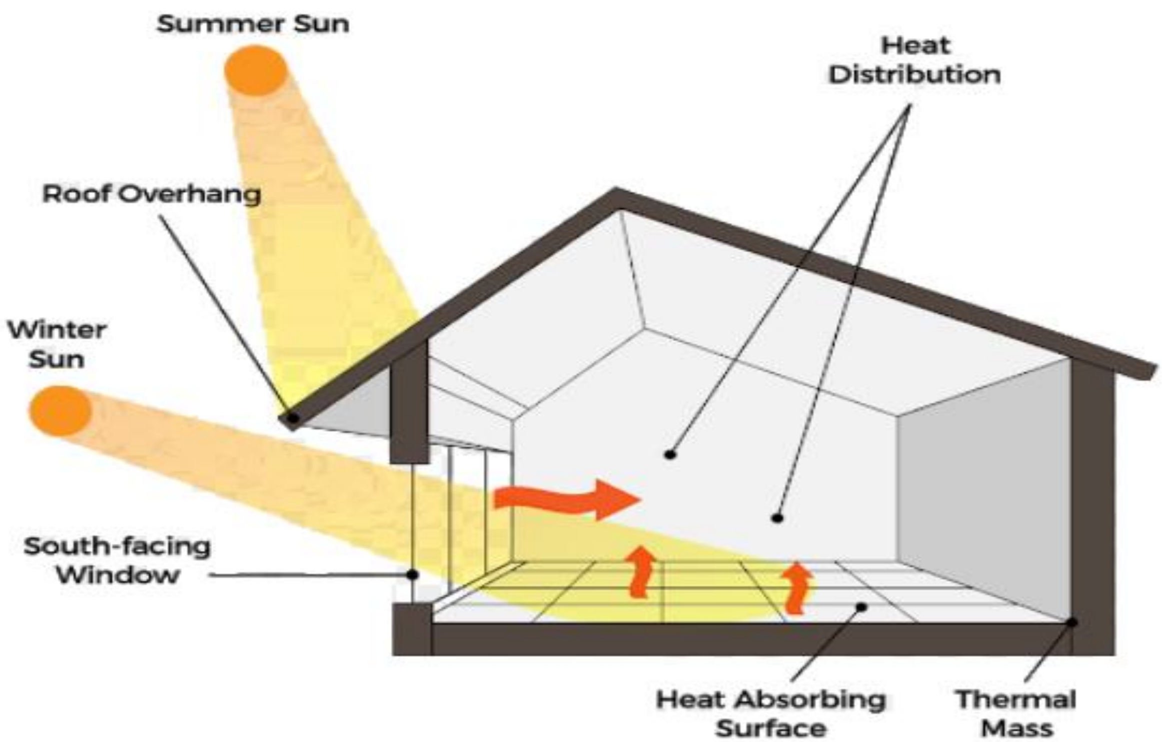


Solar technology can be broadly classified as –

✓ **Active Solar −** Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Active solar is directly consumed in activities such as drying clothes and warming of air.



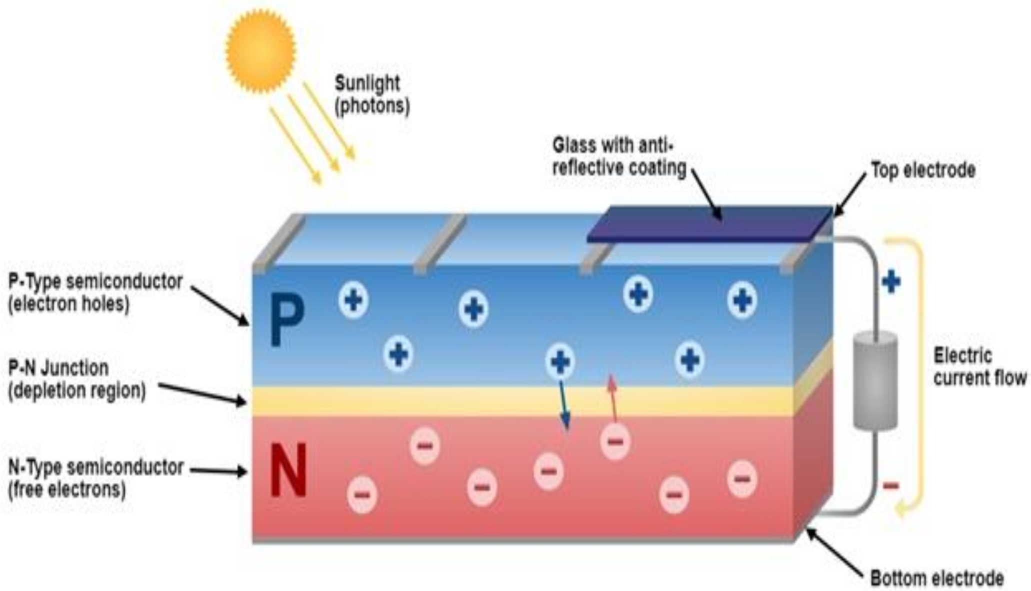
✓**Passive Solar −** Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.



Conversion of Solar Energy :

The solar energy is the energy obtained by capturing heat and light from the Sun. The method of obtaining electricity from sunlight is referred to as the Photovoltaic method. This is achieved using a semiconductor material.

The other form of obtaining solar energy is through thermal technologies, which give two forms of energy tapping methods.



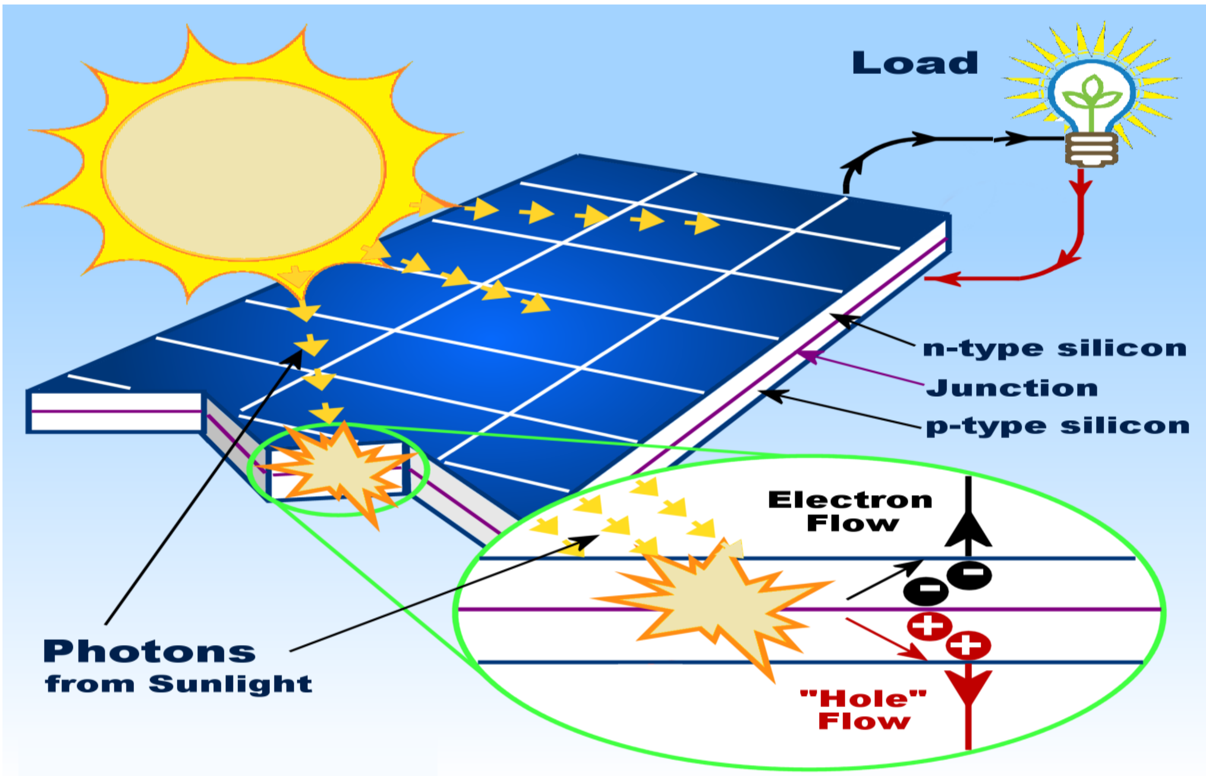
- The first is solar concentration, which focuses solar energy to drive thermal turbines.
- The second method is heating and cooling systems used in solar water heating and air conditioning respectively.

The process of converting solar energy into electricity so as to utilize its energy in day-to-day activities is given below −

- Absorption of energy carrying particles in Sun's rays called photons.
- Photovoltaic conversion, inside the solar cells.
- Combination of current from several cells. This step is necessary since a single cell has a voltage of less than 0.5 V.
- Conversion of the resultant DC to AC.

How Do Solar Panels Work?

Solar panels collect clean renewable energy in the form of sunlight and convert that light into electricity which can then be used to provide power for electrical loads. Solar panels are comprised of several individual solar cells which are themselves composed of layers of silicon, phosphorous (which provides the negative charge), and boron (which provides the positive charge). Solar panels absorb the photons and in doing so initiate an electric current.



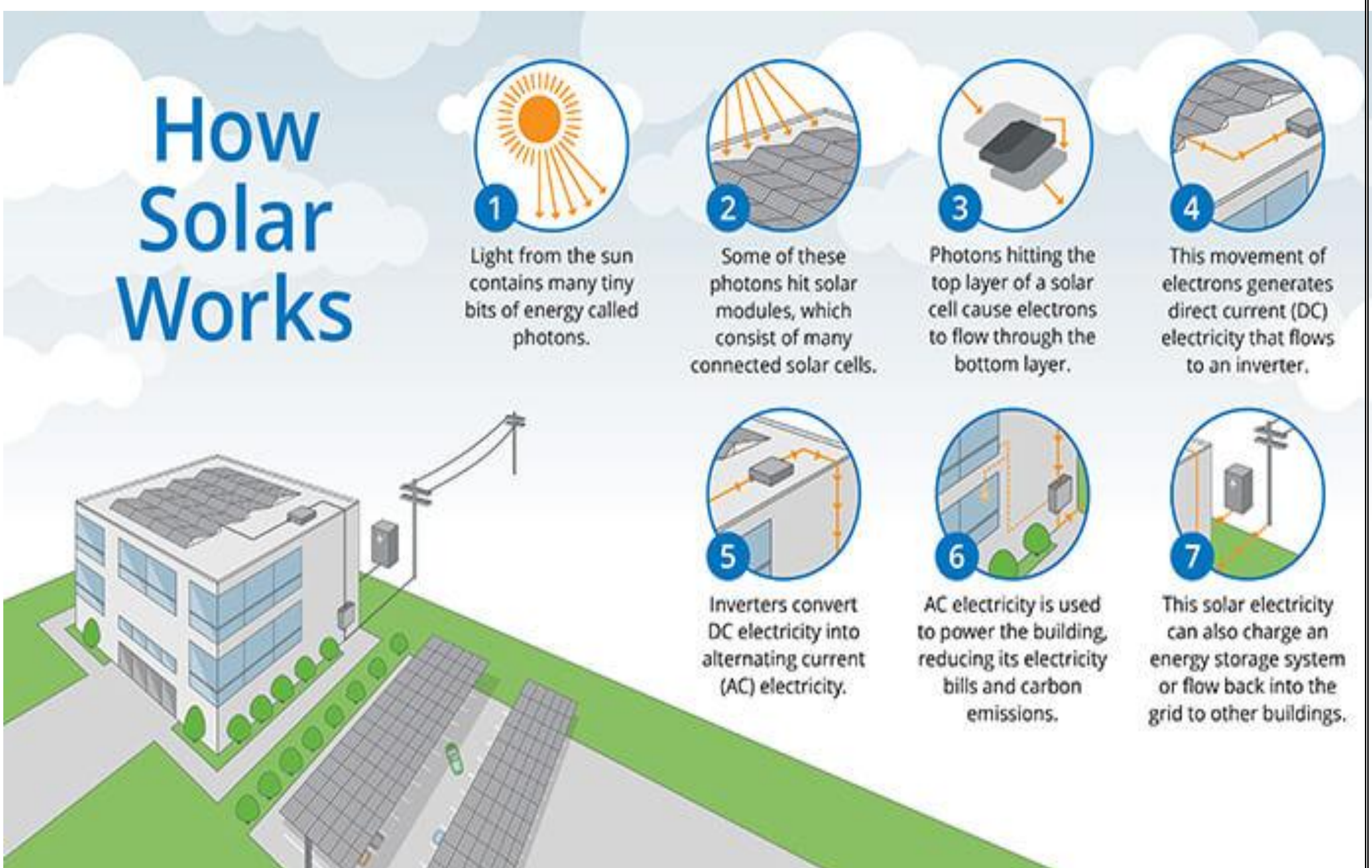
The resulting energy generated from photons striking the surface of the solar panel allows electrons to be knocked out of their atomic orbits and released into the electric field generated by the solar cells which then pull these free electrons into a directional current. This entire process is known as the Photovoltaic Effect. An average home has more than enough roof area for the necessary number of solar panels to produce enough solar electricity to supply all of its power needs excess electricity generated goes onto the main power grid, paying off in electricity use at night.

In a well-balanced grid-connected configuration, a solar array generates power during the day that is then used in the home at night. Net metering programs allow solar generator owners to get paid if their system produces more power than what is needed in the home. In off-grid solar applications, a battery bank, charge controller, and in most cases, an inverter are necessary components.

The solar array sends direct current (DC) electricity through the charge controller to the battery bank. The power is then drawn from the battery bank to the inverter, which converts the DC current into alternating current (AC) that can be used for non-DC appliances. Assisted by an inverter, solar panel arrays can be sized to meet the most demanding electrical load requirements. The AC current can be used to power loads in homes or commercial buildings, recreational vehicles and boats, remote cabins, cottages, or homes, remote traffic controls, telecommunications equipment, oil and gas flow monitoring, RTU, SCADA, and much more.

Photovoltaic (PV) cells are made of special materials called semiconductors such as silicon, which is currently the most commonly used. Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose, allowing them to flow freely.

PV cells also all have one or more electric fields that act to force electrons freed by light absorption to flow in a certain direction. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally.



The Benefits of Solar Panels :

Using solar panels is a very practical way to produce electricity for many applications. The obvious would have to be off-grid living. Living off-grid means living in a location that is not serviced by the main electric utility grid. Remote homes and cabins benefit nicely from solar power systems. No longer is it necessary to pay huge fees for the installation of electric utility poles and cabling from the nearest main grid access point. A solar electric system is potentially less expensive and can provide power for upwards of three decades if properly maintained.

Besides the fact that solar panels make it possible to live off-grid, perhaps the greatest benefit that you would enjoy from the use of solar power is that it is both a clean and a renewable source of energy. With the advent of global climate change, it has become more important that we do whatever we can to reduce the pressure on our atmosphere from the emission of greenhouse gases. Solar panels have no moving parts and require little maintenance. They are ruggedly built and last for decades when properly maintained.

Last, but not least, of the benefits of solar panels and solar power is that, once a system has paid for its initial installation costs, the electricity it produces for the remainder of the system's lifespan, which could be as much as 15-25 years depending on the quality of the system, is absolutely free!

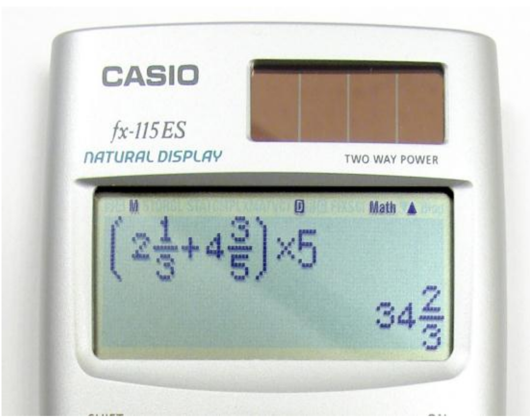
For grid-tie solar power system owners, the benefits begin from the moment the system comes online, potentially eliminating monthly electric bills or, and this is the best part, actually earning the system's owner additional income from the electric company.

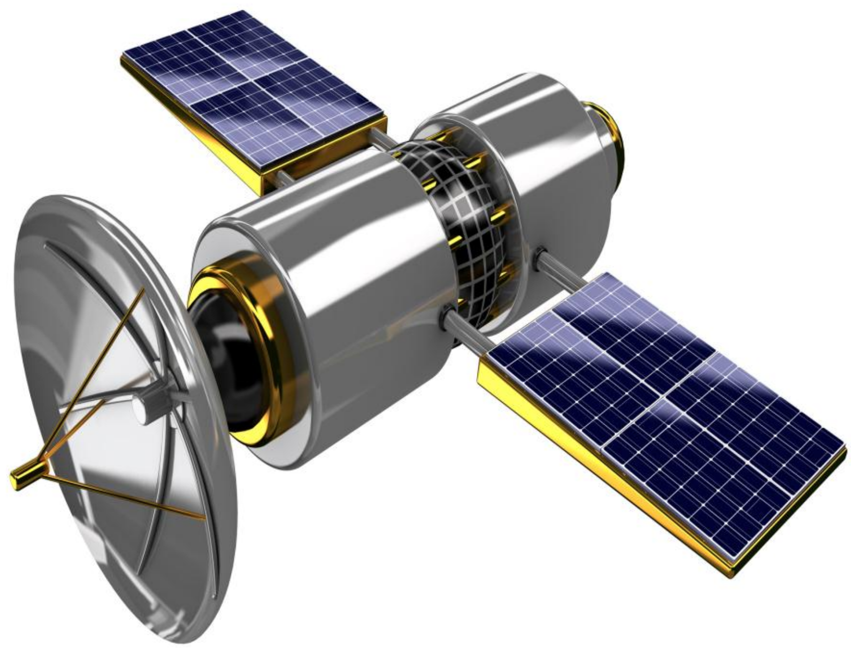
How? If you use less power than your solar electric system produces, that excess power can be sold, sometimes at a premium, to your electric utility company!

Applications Solar cells:

Solar cells have many applications. Individual cells are used for powering small devices such as electronic calculators. Photovoltaic arrays generate a form of renewable electricity, particularly useful in situations where electrical power from the grid is unavailable such as in remote area power systems, Earth-orbiting satellites and space probes, remote radiotelephones and water pumping applications. Photovoltaic electricity is also increasingly deployed in grid-tied electrical systems.

Solar cells The first spacecraft to use solar panels was the US satellite Explorer 1 in January 1958 , This milestone created interest in producing and launching a geostationary communications satellite, in which solar energy would provide a viable power supply. This was a crucial development which stimulated funding from several governments into research for improved solar cells.





Photovoltaics , or PV for short, is a solar power technology that uses solar cells or solar photovoltaic arrays to convert light from the sun directly into electricity.

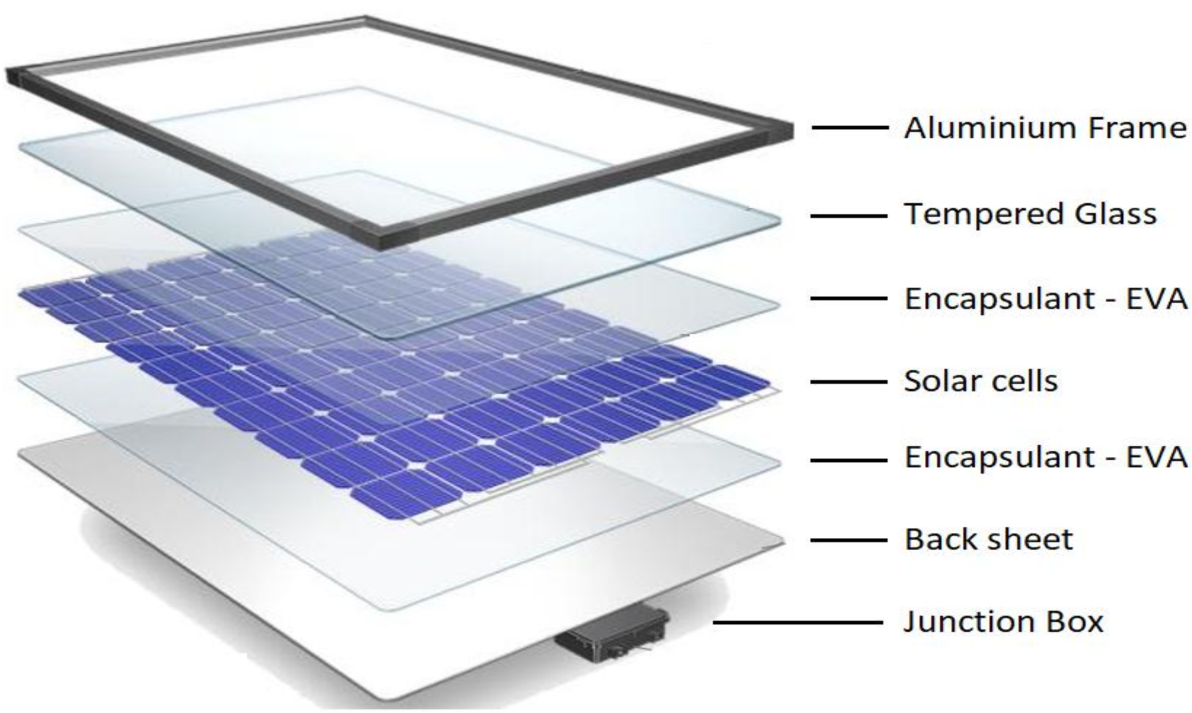
Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery.

Main Components of A Solar System

1. **Solar Panels.**
2. **Solar Inverter.**
3. **Batteries .**
4. **Electricity Switchboard.**

1. Solar Panels

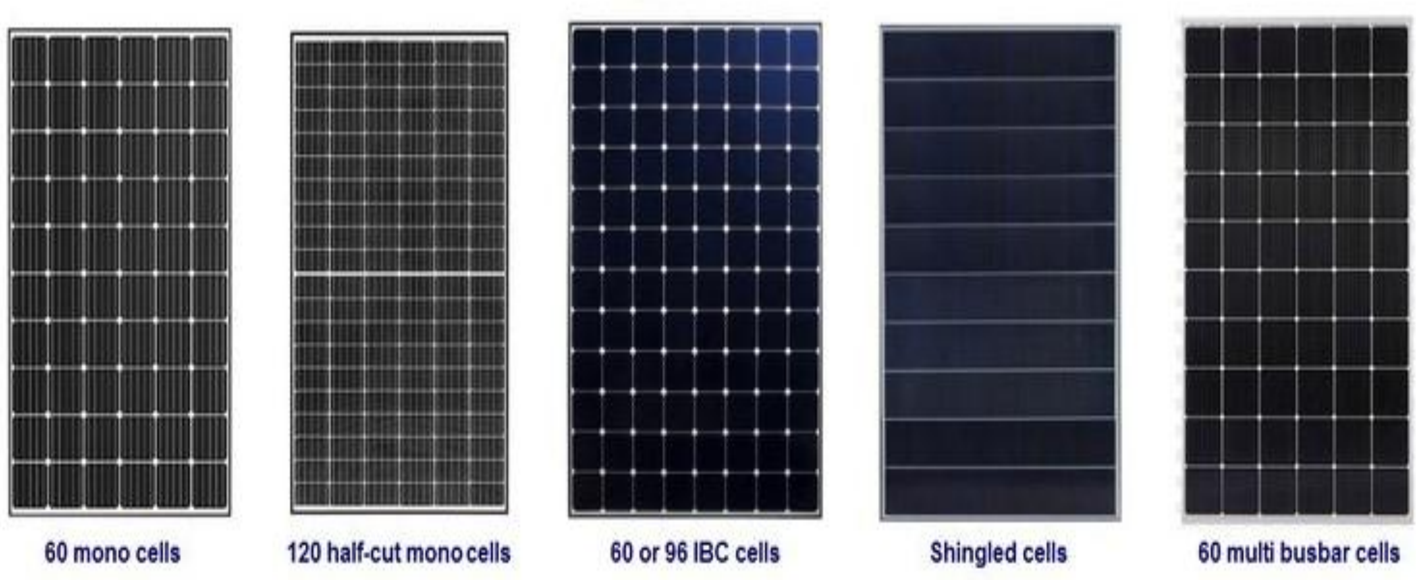
Most modern solar panels are made up of many silicon based **photovoltaic** cells (PV **cells)** which generate direct current (DC) electricity from sunlight**.** The PV cells are linked together within the solar panel and connected to adjacent panels using cables.



Note**:** It is sunlight or irradiance, not heat, which produces electricity in photovoltaic cells. Solar panels, also known as solar modules, are generally connected together in ‘strings’ to create a what is known as a solar array.

The amount of solar energy generated depends on several factors including the orientation and tilt angle of the solar panels, efficiency of the solar panel, plus any losses due to shading, dirt and even ambient temperature. There are many different solar panel manufacturers on the market, so it worth knowing which are the best solar panels and why.

Solar panels can generate energy during cloudy and overcast weather, but the amount of energy depends on the 'thickness' and height of the clouds, which determines how much light can pass through. The amount of light energy is known as solar irradiation and usually averaged over the whole day using the term Peak Sun Hours (PSH). The PSH or average daily sunlight hours depends mainly on the location and time of year.



2. Solar Inverter.

Solar panels generate DC electricity which must be converted to alternating current (AC) electricity for use in our homes and businesses. This is primary the role of the **solar inverter**. In a 'string' inverter system, the solar panels are linked together in series, and the DC electricity is brought to the inverter which converts the DC power to AC power. In a micro inverter system, each panel has its own micro-inverter attached to the rear side of the panel. The panel still produces DC, but is converted to AC on the roof and is fed straight to the electrical switchboard.

There are also more advanced string inverter systems which use small power optimisers attached to back of each solar panel. **Power optimisers** are able to monitor and control each panel individually and ensure every panel is operating at maximum efficiency under all conditions.

3. Batteries.

Batteries used for solar energy storage are available in two main types, lead-acid (**AGM & Gel**) and lithium-Ion. There are several other types available such as redox flow batteries and sodium-ion but we will focus on the most common two. Most modern energy storage systems use rechargeable lithium-ion batteries and are available in many shapes and sizes which can be configured in several ways explained.

Battery capacity is generally measured is either Amp hours (Ah) for lead-acid, or kilowatt hours (kWh) for lithium-ion. However, not all of the capacity is available for use. Lithium-ion based batteries can typically supply up to 90% of their available capacity per day, while lead-acid batteries generally only supply 30% to 40% of their total capacity per day to increase battery life. Lead-acid batteries can be discharged fully, but this should only be done in emergency backup situations.

Off-grid solar systems require specialised off-grid inverters and battery systems large enough to store energy for 2 or more days. Hybrid grid-connected systems use lower cost hybrid (battery) inverters, and only require a battery large enough to supply energy for 5 to 10 hours (overnight) depending on the application.

4. Electricity Switchboard

In a common grid-tie solar system, AC electricity from the solar inverter is sent to the switchboard where it is drawn into the various circuits and appliances in your home. This is known as Net metering, where any excess electricity generated by the solar system is sent the electricity grid through an energy meter or stored a battery storage system if you have a hybrid system. Some countries however, use ‘Gross metering’ where all solar energy is exported to the electricity grid.

Hybrid systems can both export excess electricity and store excess energy in a battery. Some Hybrid inverters maybe also be connected to a dedicated backup switchboard which enables some ‘essential circuits’ or critical loads to be powered during a grid outage or blackout.

Types of Solar Power - On-Grid, Off-Grid And Hybrid Systems

_All solar power systems work on the same basic principles. Solar panels first convert solar energy or sunlight into DC power using what is known as the photovoltaic (PV) effect. The DC power can then be stored in a battery or converted by a solar inverter into AC power which can be used to run home appliances. Depending on the type of system, excess solar energy can either be fed into the electricity grid for credits, or stored in a variety of different battery storage systems.

The three main types of solar power systems:

1. **On-grid** - also known as a grid-tie or grid-feed solar system.
2. **Off-grid** - also known as a stand-alone power system (SAPS).
3. **Hybrid** - grid-connected solar system with battery storage.

Comparision of PV System			
#	On - Grid	Off - Grid	Hybrid
Panel	YES	YES	YES
Inverter	Grid Tie Inverter	Off Grid Inverter	Hybrid Inverter
Battery	Not Required	YES	YES
Meter	Net Meter	No Special Meter Required	Net Meter
Cost	Low	Moderate	High
Power Backup When Grid Goes Down	No	YES	YES

1. *On-Grid System:*

On-grid or grid-tie solar systems are by far the most common and widely used by homes and businesses. These systems do not need batteries and use either solar inverters or micro-inverters and are connected to the public electricity grid. Any excess solar power that you generate is exported to the electricity grid and you usually get paid a feed-in-tariff (FiT) or credits for the energy you export.

On-grid means your solar system is tied to your local utility's GRID. This is what most residential homes will use because you are covered if your solar system under or over-produces in regard to your varying energy needs.

All this means for you is that your utility system acts as your battery space. If you are producing more energy with your solar panels or system than you are using, the excess energy is sent to your grid's power company, allowing you to build credit that you can cash out with at the end of the year, in a process called net metering. Being grid-tied is beneficial because you don't have to buy an expensive battery back-up system to store any excess energy.

Advantages of Grid-Tied Systems

1. Save more money with net metering

A grid-connection will allow you to save more money with solar panels through better efficiency rates, net metering, plus lower equipment and installation costs:

Batteries, and other stand-alone equipment, are required for a fully functional off-grid solar system and add to costs as well as maintenance. Grid-tied solar systems are therefore generally cheaper and simpler to install.

Your solar panels will often generate more electricity than what you are capable of consuming. With net metering, homeowners can put this excess electricity onto the utility grid instead of storing it themselves with batteries.

Net metering (or feed-in tariff schemes in some countries) play an important role in how solar power is incentivized. Without it, residential solar systems would be much less feasible from a financial point of view.

Many utility companies are committed to buying electricity from homeowners at the same rate as they sell it themselves.

2. The utility grid is a virtual battery

Electricity has to be spent in real time. However, it can be temporarily stored as other forms of energy (e.g. chemical energy in batteries). Energy storage typically comes with significant losses.

The electric power grid is in many ways also a battery, without the need for maintenance or replacements, and with much better efficiency rates. In other words, more electricity (and more money) goes to waste with conventional battery systems.

According to EIA data[1], national, annual electricity transmission and distribution losses average about 7% of the electricity that is transmitted in the United States. Lead-acid batteries, which are commonly used with solar panels, are only 80-90% efficient at storing energy, and their performance degrades with time.

Additional perks of being grid-tied include access to backup power from the utility grid (in case your solar system stop generating electricity for one reason or another). At the same time you help to mitigate the utility company`s peak load. As a result, the efficiency of our electrical system as a whole goes up.

2. Off-Grid Solar System:

An off-grid solar system (off-the-grid, standalone) is the obvious alternative to one that is grid-tied. For homeowners that have access to the grid, off-grid solar systems are usually out of question. Here`s why:

To ensure access to electricity at all times, off-grid solar systems require battery storage and a backup generator (if you live off-the-grid). On top of this, a battery bank typically needs to be replaced after 10 years. Batteries are complicated, expensive and decrease overall system efficiency.

Most of you have heard of off-grid solar systems, but not everyone understands the components that make up an off-grid system or why it may be ideal for you.

Off-grid means you're disconnected from the power grid or the local utility company, the guys that send you a bill every month.

It's important to note that both grid-tied photovoltaic systems and off-grid solar PV systems can eliminate your power bill.

However, off-grid solar photovoltaic systems are going to give you the freedom to live where you want, remotely, away from the power grid. So you can be your own power company.

We're going to take a minute to discuss the essential components of an off-grid solar energy system, starting at the Coulee mono PERC solar panels (or polycrystalline solar modules).

Mono solar panels capture the sun's energy and convert that to DC power, which is then going to be wired down to the power center, more importantly, into the charge controller that is wired to a battery bank and regulating that voltage into a battery bank to store the energy. From this stored energy were able to utilize the inverter, which is going to turn that energy into AC power that will power all your common household appliances.

In most off-grid home solar systems, a generator is included which is going to keep that charge on those batteries in the event the solar alone is not enough to do so. This has been a basic overview of the components included in an off-grid system.

Advantages of Off-Grid Solar Systems

1. No access to the utility grid

Off-grid solar systems can be cheaper than extending power lines in certain remote areas. Consider off-gird if you're more than 1000 meters from the grid. The costs of overhead transmission lines range from 25,000 $ per KM (for rural construction) to 30,000 per KM (for urban construction).

2. Become energy self-sufficient

Living off the grid and being self-sufficient feels good. For some people, this feeling is worth more than saving money. Energy self-sufficiency is also a form of security. Power failures on the utility grid do not affect off-grid solar systems.

On the flip side, batteries can only store a certain amount of energy, and during cloudy times, being connected to the grid is actually where the security is. You should install a backup generator to be prepared for these kinds of situations.

3. Hybrid Solar Systems:

Hybrid solar systems combines the best from grid-tied and off-grid solar systems. These systems can either be described as off-grid solar with utility backup power, or grid-tied solar with extra battery storage.

If you own a grid-tied solar system and drive a vehicle that runs on electricity, you already kind of have a hybrid setup. The electrical vehicle is really just a battery with wheels.

Hybrid solar systems generate power in the same way as a common grid-tie solar system but use special hybrid inverters and batteries to store energy for later use. This ability to store energy enables most hybrid systems to also operate as a backup power supply during a blackout, similar to a UPS system.

Traditionally the term hybrid referred to two generation sources such as wind and solar but in the solar world the term 'hybrid' refers to a combination of solar and energy storage which is also connected to the electricity grid.

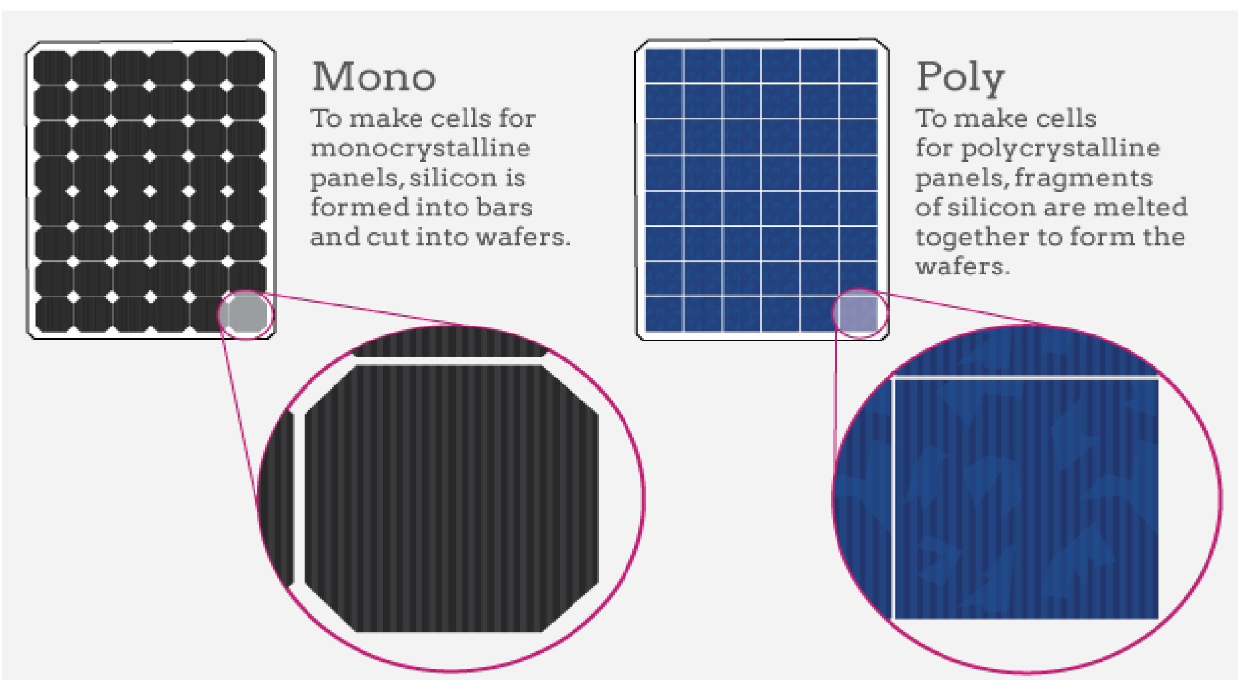
Types of Solar Panels:

When you think about installing solar panels, you usually consider factors like cost, aesthetic, and energy efficiency. While these are important factors, there is a factor in solar panels that will affect all three of these: the types of solar panels you choose. The types of solar panels on the market today will affect how much installation and manufacturing cost as well as how the panels will look on your roof. It's one of the most important considerations for a solar panel installation.

There are three types of solar panels, and each one has its pros and cons. The right solar panels will depend on your specific situation and what you hope solar panels will do for you. In this guide, we'll discuss the types of solar panels, the pros and cons of each type, and how to choose the best type of solar panel for you.

What are the 3 Type of Solar Panels?

The three types of solar panels are monocrystalline, polycrystalline, and thin-film solar panels. Each of these types of solar cells is made in a unique way and has a different aesthetic appearance. Here's the breakdown for each type of solar panel.

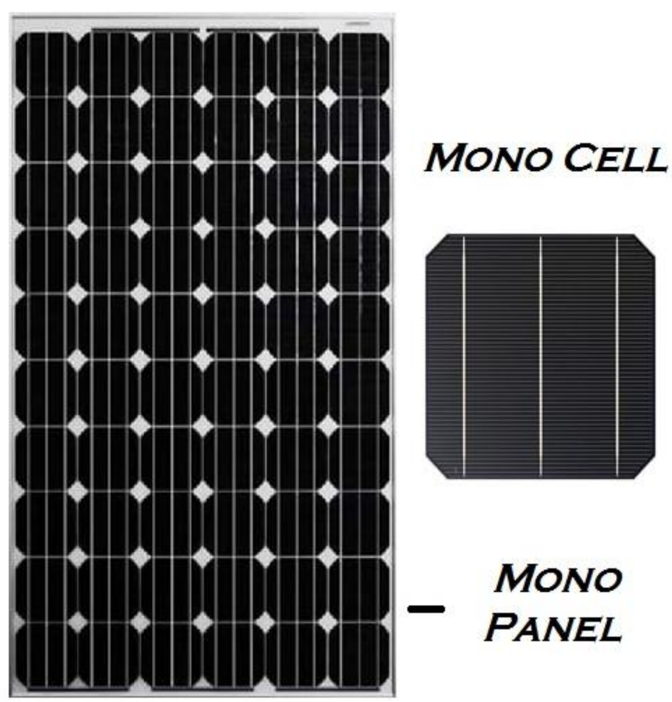


1. Monocrystalline Solar Panels (Mono-SI)

This type of solar panels (made of monocrystalline silicon) is the purest one. You can easily recognise them from the uniform dark look and the rounded edges. The silicon's high purity causes this type of solar panel has one of the highest efficiency rates, with the newest ones reaching above 20%.

Monocrystalline panels have a high power output, occupy less space, and last the longest. Of course, that also means they are the most expensive of the bunch. Another advantage to consider is that they tend to be slightly less affected by high temperatures compared to polycrystalline panels.

Monocrystalline solar panels are the oldest type of solar panel and the most developed. These solar panels are made from about 40 of the monocrystalline solar cells. These solar cells are made from pure silicon. In the manufacturing process (called the Czochralski method), a silicon crystal is placed in a vat of molten silicon. The crystal is then pulled up out of the vat very slowly, allowing for the molten silicon to form a solid crystal shell around it called an ingot. The ingot is then sliced thinly into silicon wafers. The wafer is made into the cell, and then the cells are assembled together to form a solar panel.
Monocrystalline solar cells appear black because of the way sunlights interacts with pure silicon. While the cells are black, there's a variety of colors and designs for the back sheets and frames. The monocrystalline cells are shaped like a square with the corners removed, so there are small gaps between the cells

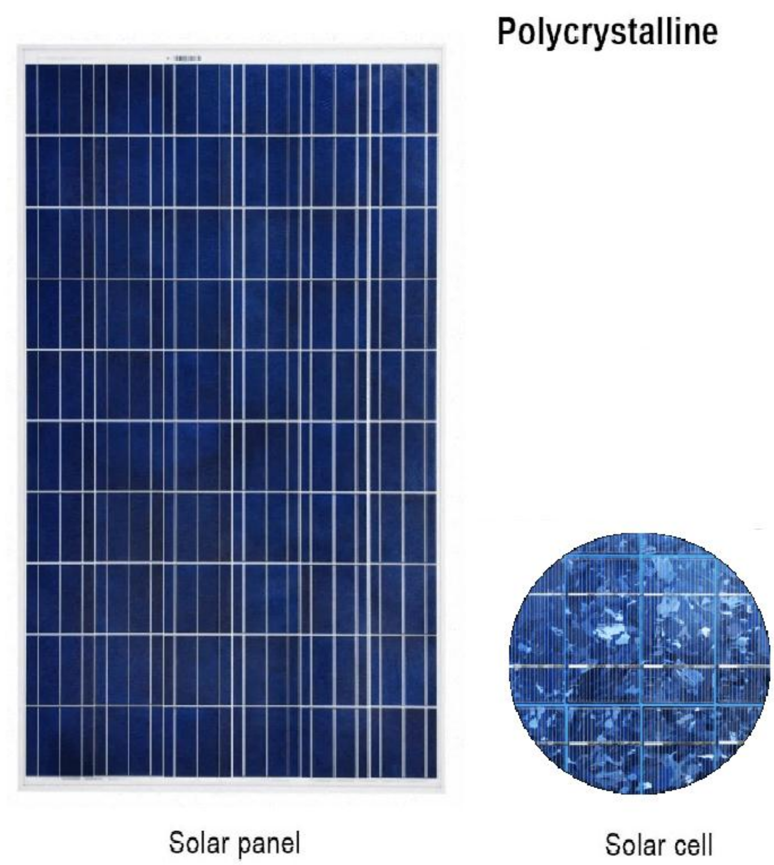


2. Polycrystalline Solar Panels (Poly-SI)

You can quickly distinguish these panels because this type of solar panels has squares, its angles are not cut, and it has a blue, speckled look. They are made by melting raw silicon, which is a faster and cheaper process than that used for monocrystalline panels.

This leads to a lower final price but also lower efficiency (around 15%), lower space efficiency, and a shorter lifespan since they are affected by hot temperatures to a greater degree. However, the differences between mono- and polycrystalline types of solar panels are not so significant and the choice will strongly depend on your specific situation. The first option offers a slightly higher space efficiency at a slightly higher price but power outputs are basically the same.

Polycrystalline solar panels are a newer development, but they are rising quickly in popularity and efficiency. Just like monocrystalline cells, polycrystalline cells are made from silicon. But polycrystalline cells are made from fragments of the silicon crystal melted together. During the manufacturing process, the silicon crystal is placed in a vat of molten silicon. Instead of pulling it out slowly, this crystal is allowed to fragment and then cool. Then once the new crystal is cooled in its mold, the fragmented silicon is thinly sliced into polycrystalline solar wafers. These wafers are assembled together to form a polycrystalline panel.

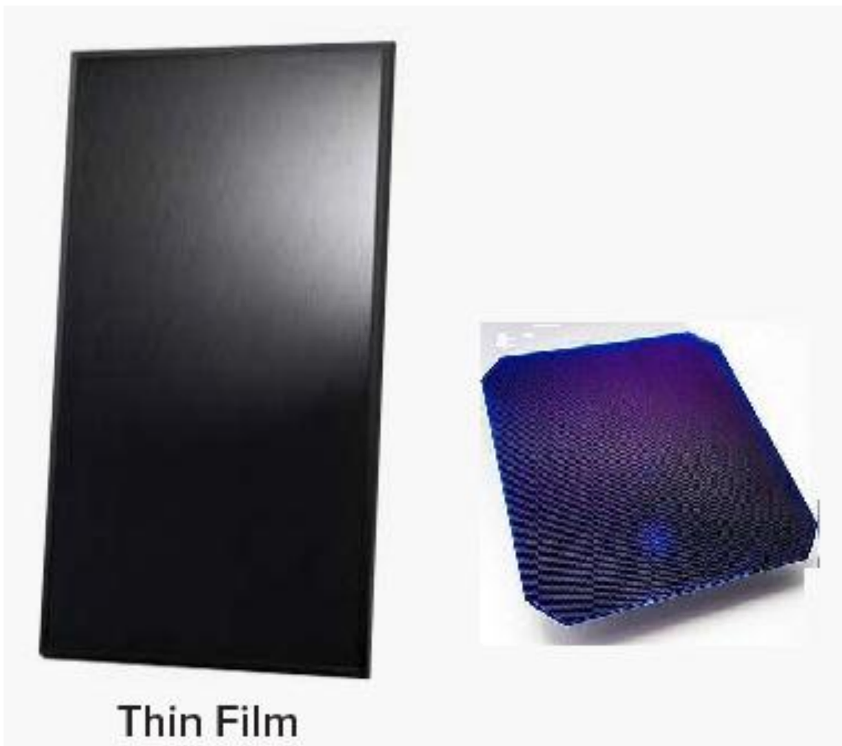


Polycrystalline cells are blue in color because of the way sunlight reflects on the crystals. Sunlight reflects off of silicon fragments differently than it does with a pure silicon cell. Usually the back frames and frames are silver with polycrystalline, but there can be variation. The shape of the cell is a square, and there are no gaps between corners of cells.

3. Thin-Film Solar Cells (TFSC)

These cells are different types of thin film solar cells and are mainly used for photovoltaic power stations, integrated in buildings or smaller solar systems.

If you are looking for a less expensive option, you might want to look into thin-film. Thin-film solar panels are manufactured by placing one or more films of photovoltaic material (such as silicon, cadmium or copper) onto a substrate. These types of solar panels are the easiest to produce and economies of scale make them cheaper than the alternatives due to less material being needed for its production.



They are also flexible—which opens a lot of opportunities for alternative applications—and is less affected by high temperatures. The main issue is that they take up a lot of space, generally making them unsuitable for residential installations. Moreover, they carry the shortest warranties because their lifespan is shorter than the mono- and polycrystalline types of solar panels. However, they can be a good option to choose among the different types of solar panels where a lot of space is available.

Thin-film solar panels are an extremely new development in the solar panel industry. The most distinguishing feature of thin-film panels is that they aren't always made from silicon. They can be made from a variety of materials, including cadmium telluride (CdTe), amorphous silicon (a-Si), and Copper Indium Gallium Selenide (CIGS). These solar cells are created by placing the main material between thin sheets of conductive material with a layer of glass on top for protection. The a-Si panels do use silicon, but they use non-crystalline silicon and are also topped with glass.

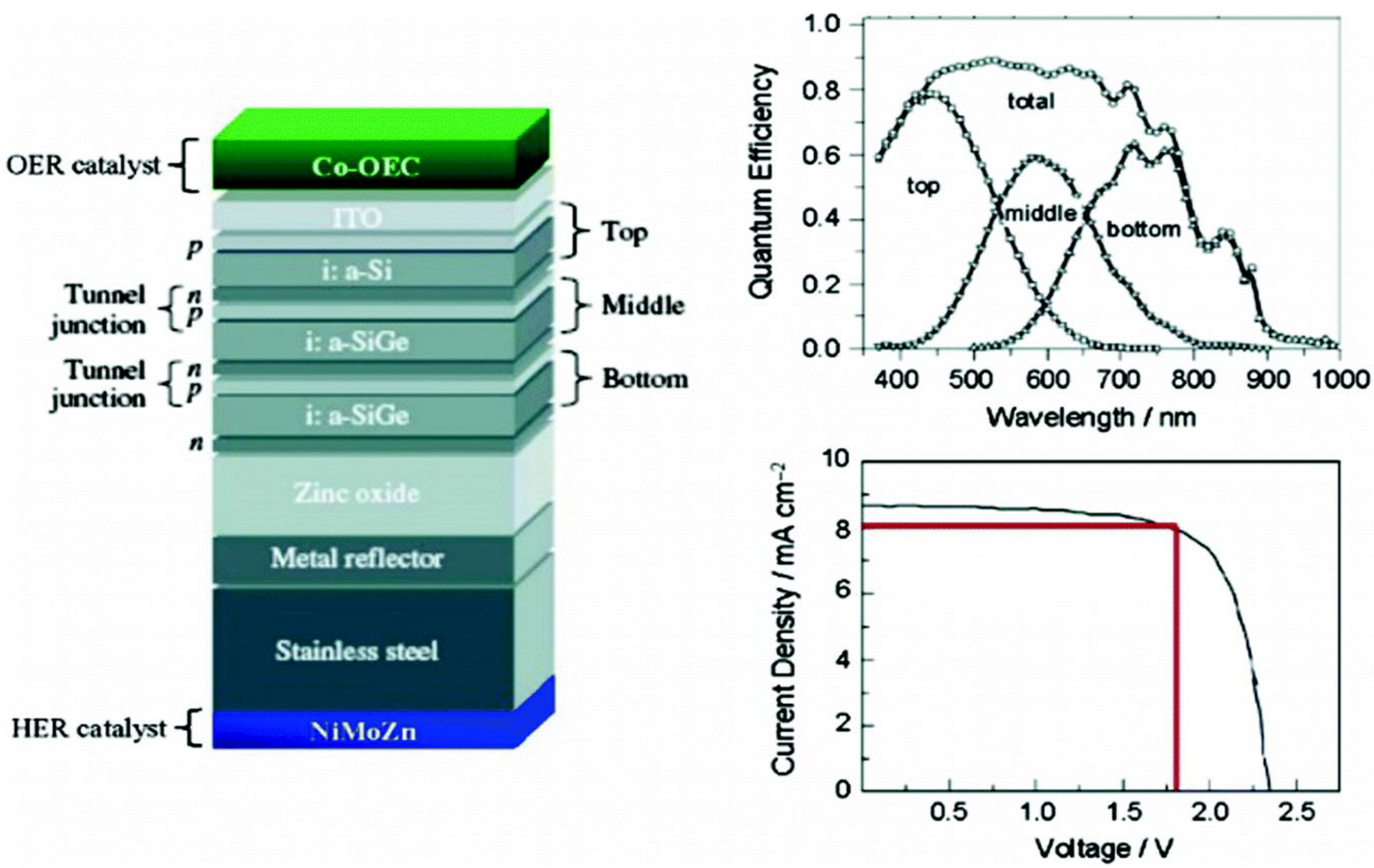
As their name suggests, thin-film panels are easy to identify by their thin appearance. These panels are approximately 350 times thinner than those that use silicon wafers. But thin-film frames can be large sometimes, and that can make the appearance of the entire solar system comparable to that of a monocrystalline or polycrystalline system. Thin-film cells can be black or blue, depending on the material they were made from.

3rd Generation Solar Panels

3rd generation solar panels include a variety of thin film technologies but most of them are still in the **research or development phase**. Some of them generate electricity by using organic materials, others use inorganic substances (CdTe for instance).

Biohybrid Solar Cell

The Biohybrid solar cell is one of the types of solar panels, that is still in the research phase. It has been discovered by an expert team at Vanderbilt University. The idea behind the new technology is to take advantage of the photosystem 1 and thus emulate the natural process of photosynthesis. In case you want to learn more about how the biohybrid solar cell works in detail, read more about it in the American Journal of Optics and Photonics. It explains more detailed how these cells work. Many of the materials being used in this cell are similar to the traditional methods, but only by combining the multiple layers of photosystem 1, the conversion from chemical to electrical energy becomes much more effective (up to 1000 times more efficient than 1st generation types of solar panels).



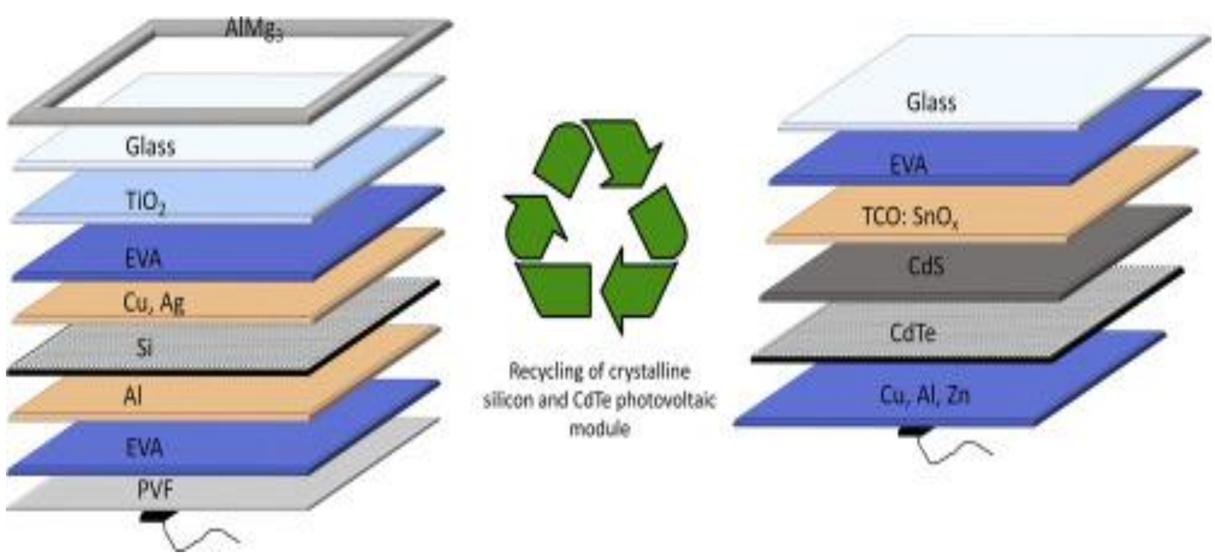
Cadmium Telluride Solar Cell (CdTe)

Among the collection of different types of solar panels, this photovoltaic technique uses Cadmium Telluride, which enables the production of solar cells at relatively low cost and thus a shorter payback time (less than a year). Of all solar energy technologies, this is the one requiring the least amount of water for production. Keeping the short energy payback time in mind, CdTe solar cells will keep your carbon footprint as low as possible. The only disadvantage of using Cadmium Telluride is its characteristic of being toxic, if ingested or inhaled. In Europe especially, this is one of the greatest barriers to overcome, as many people are very concerned about using the technology behind this type of solar panel.

Cadmium telluride (CdTe) photovoltaics describes a photovoltaic (PV) technology that is based on the use of cadmium telluride in a thin semiconductor layer designed to absorb and convert sunlight into electricity.[1] Cadmium telluride PV is the only thin film technology with lower costs than conventional solar cells made of crystalline silicon in multi-kilowatt systems.

On a lifecycle basis, CdTe - PV has the smallest carbon footprint, lowest water use and shortest energy payback time of any current photo voltaic technology. CdTe's energy payback time of less than a year allows for faster carbon reductions without short-term energy deficits.

The toxicity of cadmium is an environmental concern mitigated by the recycling of CdTe modules at the end of their life time. Though there are still uncertainties regarding the recycling of CdTe modules and the public opinion is skeptical towards this technology. The usage of rare materials may also become a limiting factor to the industrial scalability of CdTe technology in the mid-term future. The abundance of tellurium—of which telluride is the anionic form—is comparable to that of platinum in the earth's crust and contributes significantly to the module's cost.



Concentrated PV Cell (CVP and HCVP)

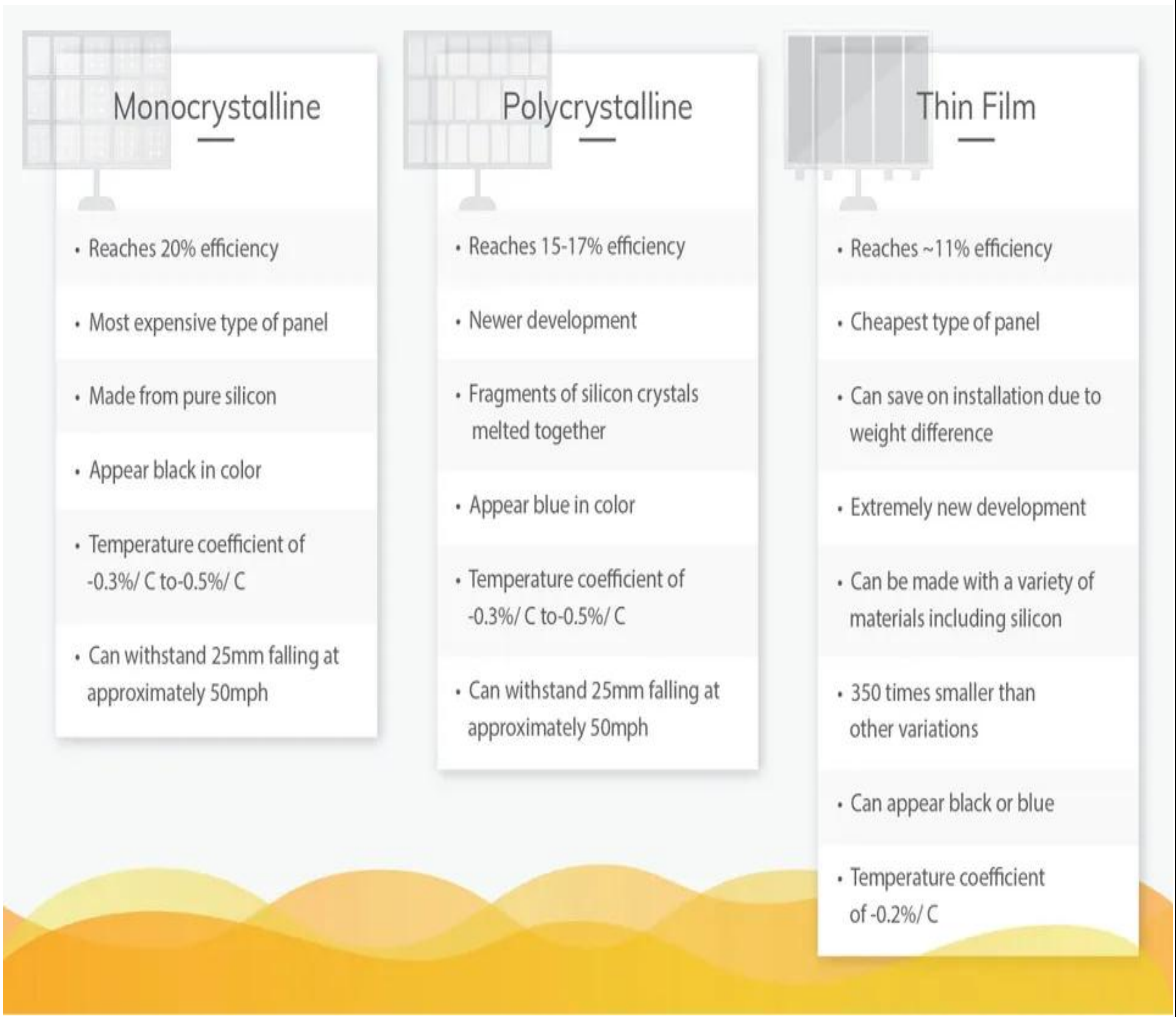
Concentrated PV cells generate electrical energy just as conventional photovoltaic systems do. Those multi-junction types of solar panels have an efficiency rate up to 41%, which, among all photovoltaic systems, is the highest so far.

The name of such CVP cells is related to what makes them so efficient, compared to other types of solar panels: curved mirror surfaces, lenses and sometimes even cooling systems are used to bundle the sun rays and thus increase their efficiency.

By this means, CVP cells have become one of the most efficient solar panels, with a high performance and efficiency rate of up to 41%. What remains is the fact, that such CVP solar panels can only be as efficient if they face the sun in a perfect angle. In order to reach such high efficiency rates, a solar tracker inside the solar panel is responsible for following the sun.

Different between Monocrystalline and polycrystalline and Thin-Film solar panels:

Besides manufacturing and appearance, there are some differences in how each of the types of solar cells performs. The key categories are efficiency and price. Here's how each type of solar panel performs in efficiency and affordability as well as other factors to consider.



Efficiency:

Efficiency is how much energy the solar panel can produce from the amount of sunlight it receives. Essentially, efficiency determines how much power a solar panel can produce. The most efficient solar panel is the monocrystalline panels. Monocrystalline can reach over 20 percent efficiency. On the other hand, polycrystalline panels can usually only reach 15 to 17 percent efficiency. This gap between the two panels may be closing in the future as technology improves to make polycrystalline panels more efficient. The least efficient solar panel is the thin-film. Thin-film usually has lower efficiency and produces less power than either of the crystalline options with efficiency at only approximately 10 percent. The power capacity of a thin-film panel can vary though because there isn't a standard size, and some models could produce more power than others.

Cell type	Efficiency rate	Lifespan	Advantages	Disadvantages
Monocrystalline	20 %	25 years	Highly efficient, durable	Expensive
Polycrystalline	16 %	25 years	Lower cost	Less efficient
Thin-film (Amorphous)	10 %	15-20 years	Less expensive, easily produced	Lower efficiency/ shorter lifespan

Cost:

Price can make or break a solar decision, and the types of solar cells you choose is one of the factors that affects price the most. The cheapest solar panels are thin-film panels because they can be manufactured at the lowest cost. The CdTe are the cheapest solar panels on the market, but the CIGS can be more expensive. Thin-film frames are usually lighter, so you can often save on installation costs. On the other hand, monocrystalline is the most expensive solar panel option right now. Manufacturing pure silicon can be expensive, and the panels and frames are heavy, leading to higher installation costs. Polycrystalline panels were developed to reduce the cost of solar panels, and they are usually more affordable than monocrystalline. But this gap between monocrystalline and polycrystalline panels may close as innovators discover more efficient ways to manufacture monocrystalline solar cells.

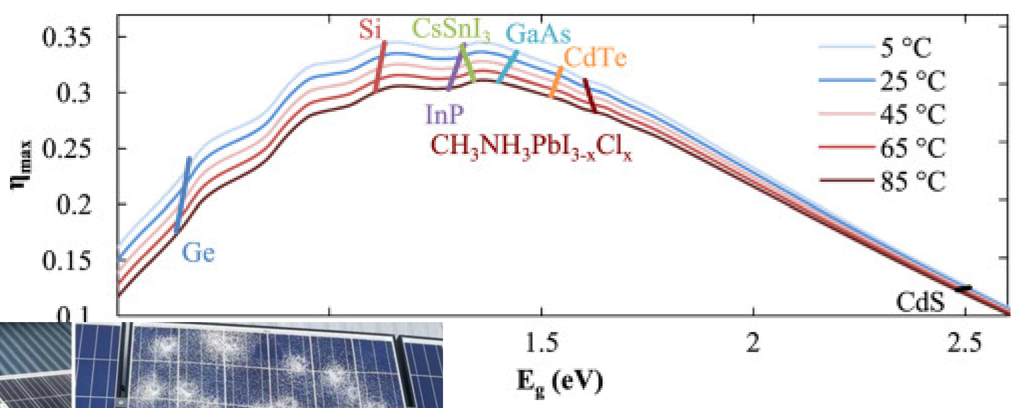
Other Factors - Temperature Coefficient, Hail Resistance, Fire Resistance, UL & IEC Listings etc.:

Besides cost and efficiency, there are several other factors to consider when choosing solar panels. One factor is the temperature coefficient. Monocrystalline and polycrystalline solar panels typically have a temperature coefficient around -0.3% / °C to -0.5% / °C. Thin-film panels have coefficients closer to -0.2% / °C.

What this means is that as the temperature rises, certain types of solar panels will produce more power than others. This is especially important to consider in an area like North Carolina, where the temperature highs can be significant.

Another factor to consider is the fire rating, which can vary based on the type of roof you have and the type of panel you choose. Fire isn't the only natural disaster that can strike your roof, so you'll also want to consider hail ratings. Most monocrystalline and polycrystalline panels can withstand 25mm falling at approximately 50 miles per hour, but the exact rating can vary and can affect the lifespan of your solar system. You also may want to consider finding heterojunction solar cell technology (HJT) for your system that combines monocrystalline silicon wafers with amorphous silicon. HJT has peak efficiency with the lowest temperature coefficient and no Light Induced Degradation (LID). Finally, you'll want to consider LID because degradation of efficiency can affect the amount of energy you're able to produce.

All of these various factors are considered by our engineers when designing and recommending a solar PV system. We look at the overall system lifecycle and efficiency not just in ideal scenarios but in all conditions that your solar PV system will be subjected to.



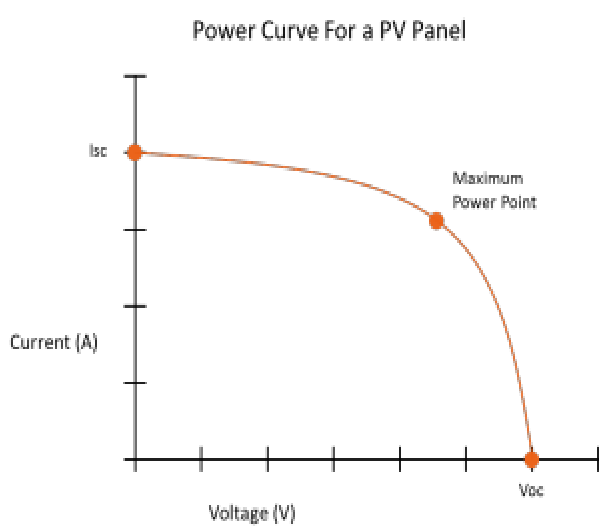
The Best Type of Solar Panels:

The best type of solar panels depends on the purpose of the panels and where they'll be installed. For residential properties with a large roof space or property, the best choice of panels may be polycrystalline. These panels are the most affordable for large spaces and will provide enough efficiency and power. For residential properties with smaller spaces, monocrystalline may be the best choice. These panels work well for those who want to maximize their energy bills in a small space. Monocrystalline and polycrystalline panels are good fits for homes and other similar buildings. Thin-film solar panels are almost never used on homes because they are lower in efficiency. Instead, thin-film solar panels are perfect for commercial buildings that can't handle the additional weight of traditional panels. Though thin-film is less efficient, commercial roofs have more space to cover more of the roof with panels.

Types of Solar Charge Controller:

1. **PWM: Pulse-Width Modulation**
2. **MPPT: Maximum Power Point Tracking**

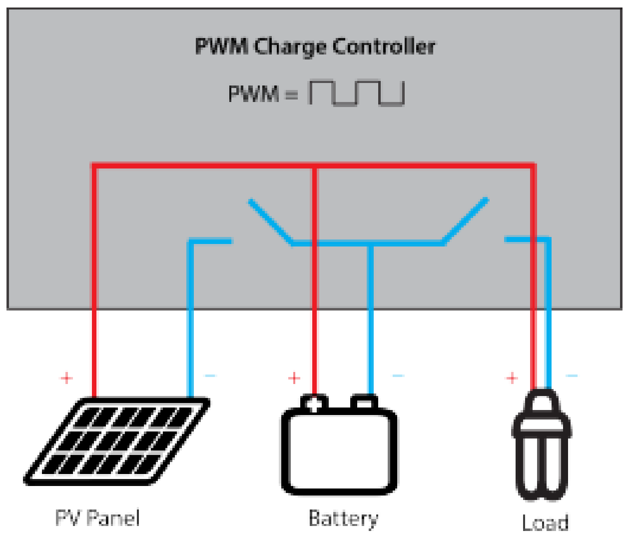
PWM and MPPT are the two different types of charging methods solar charge controllers can use to charge batteries from a solar array/panel. Both technologies are widely used in the off-grid solar industry and are both great options for efficiently charging your battery. The decision to use PWM or MPPT regulation is not purely based on which power charging method is "better" than the other. Moreover, it involves determining which type of controller will work best in your system's design. To understand the difference between PWM and MPPT charging, let's first look at a typical power curve of a PV panel. The power curve is important because it states the expected power generation of the panel based on the combination voltage ("V") and current ("I") generated by the panel. The optimal ratio of current to voltage to produce the most power is known as the "Maximum Power Point" (MPPT). The MPPT will change dynamically throughout the day depending on irradiation conditions.



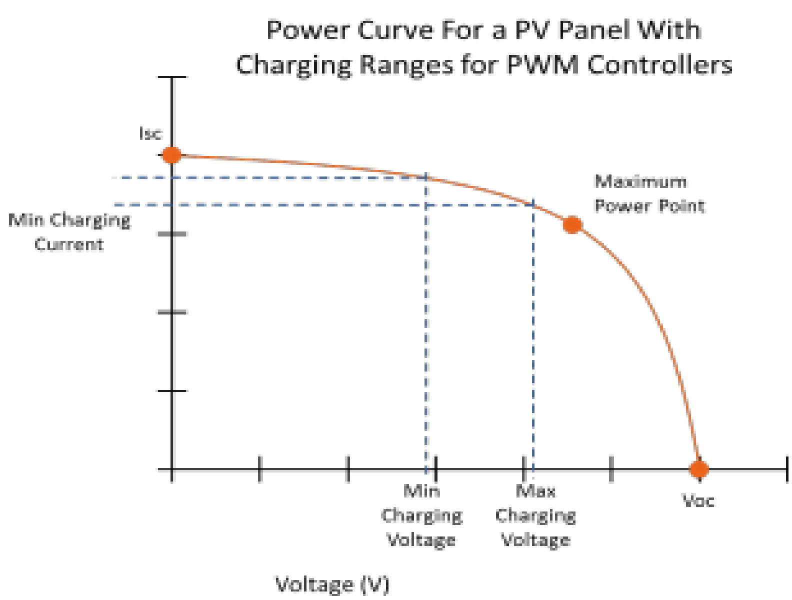
**Most often you can find the power curve for your PV panel on the product's datasheet.*

1. PWM Charge Controllers

Pulse-Width Modulation (PWM) comes into play when the battery bank is full. During charging, the controller allows as much current as the PV panel/array can generate in order to reach the target voltage for the charge stage the controller is in. Once the battery approaches this target voltage, the charge controller quickly switches between connecting the battery bank to the panel array and disconnecting the battery bank, which regulates the battery voltage holding it constant. This quick switching is called PWM and it ensures your battery bank is efficiently charged while protecting it from being overcharged by the PV panel/array.

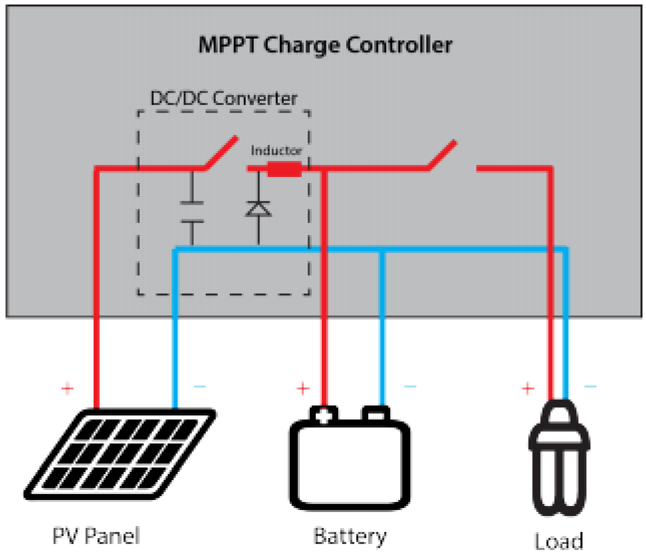


PWM controllers will operate close to the maximum power point but often slightly “above” it. An example operating range is shown below.

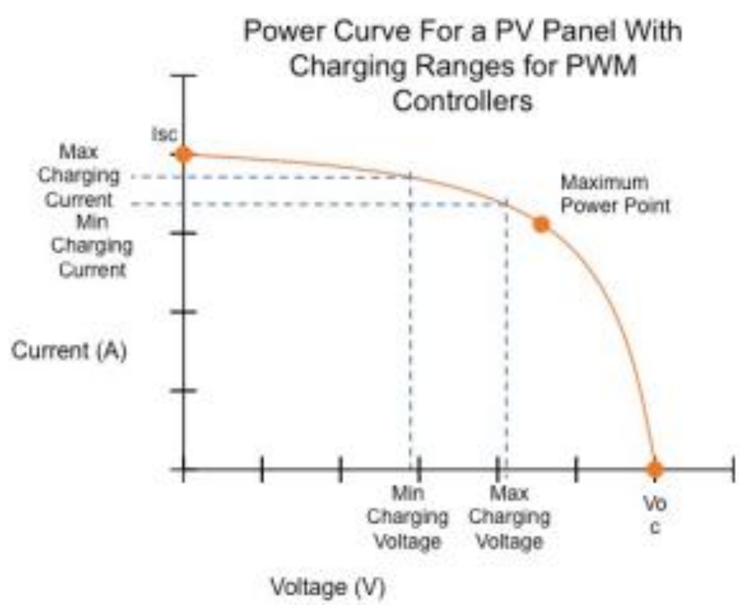


2. MPPT Charge Controllers

Maximum Power Point Tracking features an indirect connection between the PV array and the battery bank. The indirect connection includes a DC/DC voltage converter that can take excess PV voltage and convert it into extra current at a lower voltage without losing power.

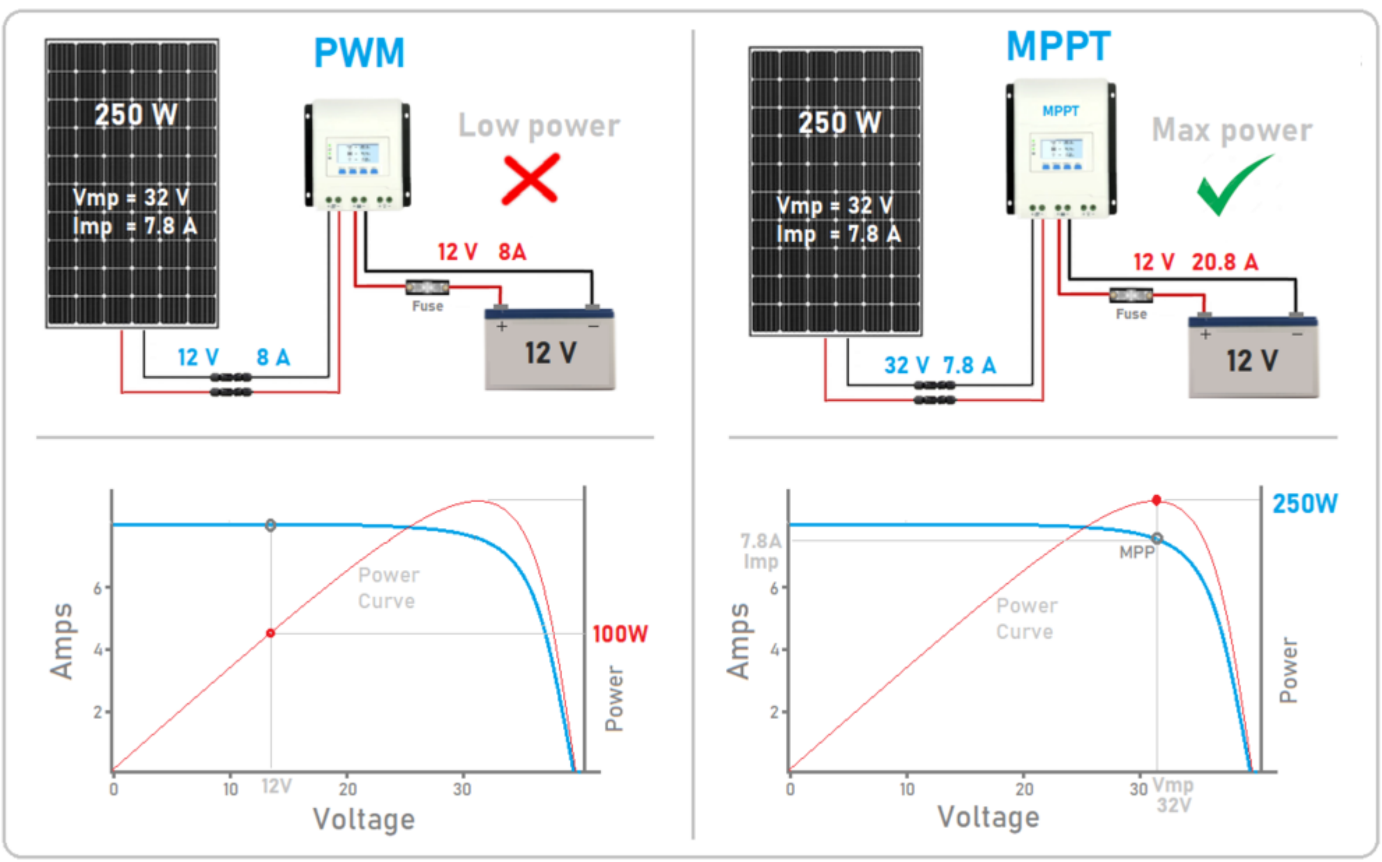


MPPT controllers do this via an adaptive algorithm that follows the maximum power point of the PV array and then adjusts the incoming voltage to maintain the most efficient amount of power for the system.



Pros and Cons of Both Types of Controllers

	PWM	MPPT
Pros	1/3 – 1/2 the cost of a MPPT controller.	Highest charging efficiency (especially in cool climates).
	Longer expected lifespan due to fewer electronic components and less thermal stress.	Can be used with 60-cell panels.
	Smaller size	Possibility to oversize array to ensure sufficient charging in winter months.
Cons	PV arrays and battery banks must be sized more carefully and may require more design experience.	2-3 times more expensive than a comparable PWM controller.
	Cannot be used efficiently with 60-cell panels.	Shorter expected lifespan due to more electronic components and greater thermal stress.



This comparison highlights the problem with using a higher voltage solar panel on a 12V battery without MPPT

Reference :

1. https://slideplayer.com/slide/3787169/
2. https://www.tutorialspoint.com/renewable_energy/solar_energy_introduction.htm
3. https://www.mrsolar.com/what-is-a-solar-panel/
4. https://www.greenmatch.co.uk/blog/2015/09/types-of-solar-panels
5. https://www.energysage.com/solar/101/monocrystalline-vs-polycrystalline-solar-panels/
6. https://www.8msolar.com/types-of-solar-panels
7. https://www.cleanenergyreviews.info/blog/2014/5/4/how-solar-works
8. https://en.wikipedia.org/wiki/Cadmium_telluride_photovoltaics
9. https://www.cleanenergyreviews.info/blog/2014/8/14/what-is-hybrid-solar
10. https://www.solarreviews.com/blog/grid-tied-off-grid-and-hybrid-solar-systems
11. https://www.phocos.com/wp-content/uploads/2019/11/Guide-Comparing-PWM-MPPT-Charge-Controllers.pdf

Index of Contents:

Bands	Pages

Index of Contents:

Bands **Pages**