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Solar Module Technology Overview

1. Mono-crystalline Silicon Solar Cells

Solar cells made of mono-crystalline silicon (mono-Si), also called single-crystalline silicon (single-crystal-Si), are quite easily recognizable by an external even colouring and uniform look, indicating high-purity silicon.

Mono-crystalline solar cells are made out of silicon ingots, which are cylindrical in shape. To optimize performance and lower costs of a single mono-crystalline solar cell, four sides are cut out of the cylindrical ingots to make silicon wafers, which is what gives mono-crystalline solar panels their characteristic look.

A good way to separate mono- and Poly-crystalline solar panels is that Poly-crystalline solar cells look perfectly rectangular with no rounded edges.

- Advantages

Mono-crystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon. The efficiency rates of mono-crystalline solar panels are typically 18-22%.

Mono-crystalline silicon solar panels are space-efficient. Since these solar panels yield the highest power outputs, they also require the least amount of space compared to any other types.

Mono-crystalline solar panels produce up to four times the amount of electricity as thin-film solar panels.

- Disadvantages

Mono-crystalline solar panels are the most expensive. From a financial standpoint, a solar panel that is made of Poly-crystalline silicon (and in some cases thin-film) can be a better choice for some homeowners.

If the solar panel is partially covered with shade, dirt or snow, the entire circuit can break down. Consider getting micro-inverters instead of central string inverters if you think coverage will be a problem. Micro-inverters will make sure that not the entire solar array is affected by shading issues with only one of the solar panels.

The Czochralski process is used to produce mono-crystalline silicon. It results in large cylindrical ingots. Four sides are cut out of the ingots to make silicon wafers. A significant amount of the original silicon ends up as waste.

Mono-crystalline solar panels tend to be more efficient in warm weather. Performance suffers as temperature goes up, but less so than Poly-crystalline solar panels. For most homeowners temperature is not a concern.

2. Poly-crystalline Silicon Solar Cells

The first solar panels based on Poly-crystalline silicon, which also is known as Poly-silicon (p-Si) and multi-crystalline silicon (mc-Si), were introduced to the market in 1981. Unlike mono-crystalline-based solar panels, Poly-crystalline solar panels do not require the Czochralski process. Raw silicon is melted and poured into a square mould, which is cooled and cut into perfectly square wafers.

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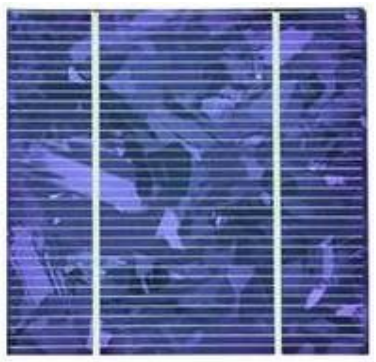
- Advantages



The process used to make Poly-crystalline silicon is simpler and cost less. The amount of waste silicon is less compared to mono-crystalline.

Poly-crystalline solar panels can tend to have slightly lower heat tolerance than mono-crystalline solar panels. This technically means that they perform slightly worse than mono-crystalline solar panels in high temperatures. Heat can affect the performance of solar panels and shorten their lifespans. However, this effect is now very minor, and most people do not need to take it into account.

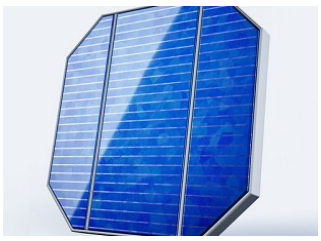
- Disadvantages

The efficiency of Poly-crystalline-based solar panels will be lower than mono due to numerous crystals instead of one single one, however multi-junction cells are making this less of an issue.

Lower space-efficiency

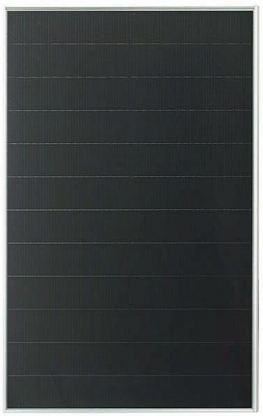
You generally need to cover a marginally larger surface to output the same electrical power as you would with a solar panel made of mono-crystalline silicon. However, this does not mean every mono-crystalline solar panel performs better than those based on Poly-crystalline silicon. For instance a 260W poly would be the same area as a 280W mono.

3. Passivated Emitter Rear Cell technology (PERC)



PERC technology increases conversion efficiency by adding a dielectric passivation layer at the rear side of the cell, most commonly a mono-crystalline cell. Higher efficiency levels in standard cell architectures are limited by the tendency for photo generated electrons to recombine. PERC cells maximize the electrical gradient across the p-n junction, which allows for a steadier flow of electrons, reduction in electron recombination, and higher efficiency levels. So basically the PERC technology is a way to increase the production capability of a standard mono or polycrystalline cell. Given its high yielding advantages its most common to add this to a mono module.

4. Thin-Film Solar Cells (TFSC)



Depositing one or several thin layers of photovoltaic material onto a substrate is the basic gist of how thin-film solar cells are manufactured. They are also known as thin-film photovoltaic cells (TFPV). The different types of thin-film solar cells can be categorized by which photovoltaic material is deposited onto the substrate:

- Amorphous silicon (a-Si)
- Cadmium telluride (CdTe)
- Copper indium gallium selenide (CIS/CIGS)
- Organic photovoltaic cells (OPC)

Depending on the technology, thin-film module prototypes have reached efficiencies between 7–15% and production modules operate at about 11%. Future module efficiencies are expected to climb close to the about 12–18%.

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The market for thin-film PV grew at a 60% annual rate from 2002 to 2007. In 2011, close to 5% of U.S. photovoltaic module shipments to the residential sector were based on thin-film.

- Advantages

Mass-production is simple. This makes them and potentially cheaper to manufacture than crystalline-based solar cells.

- Their homogenous appearance makes them look more appealing.
- Can be made flexible, which opens up many new potential applications.
- High temperatures and shading have less impact on solar panel performance.
- In situations where space is not an issue, thin-film solar panels can make sense.
- Disadvantages

Thin-film solar panels are in general not very useful for in most residential situations. They are cheap, but they also require a lot of space.

Low space-efficiency also means that the costs of PV-equipment (e.g. support structures and cables) will increase.

Thin-film solar panels tend to degrade faster than mono- and Poly-crystalline solar panels, which is why they typically come with a shorter warranty

Solar panels based on amorphous silicon, cadmium telluride and copper indium gallium Selenide are currently the only thin-film technologies that are commercially available on the market:

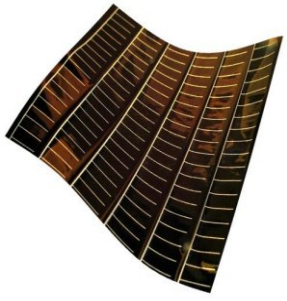
5. Amorphous Silicon (a-Si) Solar Cells

Because the output of electrical power is low, solar cells based on amorphous silicon have traditionally only been used for small-scale applications such as in pocket calculators. However, recent innovations have made them more attractive for some large-scale applications too.

With a manufacturing technique called “stacking”, several layers of amorphous silicon solar cells can be combined, which results in higher efficiency rates (typically around 6-8%).

Only 1% of the silicon used in crystalline silicon solar cells is required in amorphous silicon solar cells. On the other hand, stacking is expensive.

6. Cadmium Telluride (CdTe) Solar Cells



Cadmium telluride is the only thin-film solar panel technology that has surpassed the cost-efficiency of crystalline silicon solar panels in a significant portion of the market (multi-kilowatt systems).

The efficiency of solar panels based on cadmium telluride usually operates in the range 9-11%.

First Solar has installed over 5 GigaWatt (GW) of cadmium telluride thin-film solar panels worldwide. The same company holds the world record for CdTe PV module efficiency of 14.4%.

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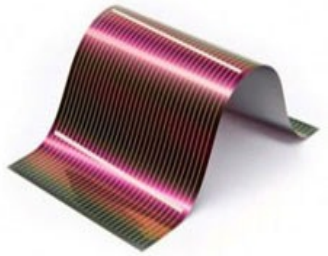
7. Copper Indium Gallium Selenide (CIS/CIGS) Solar Cells



Compared to the other thin-film technologies above, CIGS solar cells have showed the most potential in terms of efficiency. These solar cells contain less amounts of the toxic material cadmium that is found in CdTe solar cells. Commercial production of flexible CIGS solar panels was started in Germany in 2011.

The efficiency rates for CIGS solar panels typically operate in the range 10-12 %.

Many thin-film solar cell types are still early in the research and testing stages. Some of them have enormous potential, and we will likely see more of them in the future.

8. Building-Integrated Photovoltaics (BIPV)

Building Integrated Photovoltaics, rather than an individual type of solar cell technology is a primarily a method of installation. Building integrated Photovoltaics have several subtypes (or different methods of integration), which can be based on both crystalline-based and thin-film solar cells.

Building integrated Photovoltaics can be facades, roofs, windows, walls and many other things that is combined with photovoltaic material. If you have the extra money and want to seamlessly integrate Photovoltaics with the rest of your home, you should look up building integrated Photovoltaics.

Often though BIPV will be double glazed and not have the usual back sheet so that for the most part the panels are see through.

Overall Recommendations

For those who don't have enough space for thin-film solar panels (the majority of domestic users), or if you want to limit the amount of space their PV-system takes up, crystalline-based solar panels are your best choice (and they would likely be the best choice even if you had the extra space). There are not a whole lot of solar installers and providers that offer thin-film solar panels for homeowners at this point.

You will have a choice of different solar panel sizes. The 250, 260 and even 310-watt rated solar panels are usually physically the same size. They are manufactured exactly the same way, but under- or over perform when tested, hence ending up in different categories for power output. If size is important, you should go for the highest rated power output for a particular physical size.

Both mono- and Poly-crystalline solar panels are good choices and offer similar advantages. Even though Poly-crystalline solar panels tend to be less space-efficient and Mono-crystalline solar panels tend to produce more electrical power, this is not always the case. It would be nearly impossible to recommend one or the other by not examining the solar panels and your situation closer.

Mono-crystalline solar panels are slightly more expensive, but also slightly more space-efficient. If you had one Poly-crystalline and one Mono-crystalline solar panel, both rated 275-watt, they would generate the same amount of electricity, but the one made of Mono-crystalline silicon would take up less space. However in real terms its actually space related, for instance a 60 cell module that is 92cm by 162cm would be 260W in Poly and maybe 275W in mono..