Solar Cell Book

Solar Energy Basic Information Guide

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Solar Cell & Energy Information Guide

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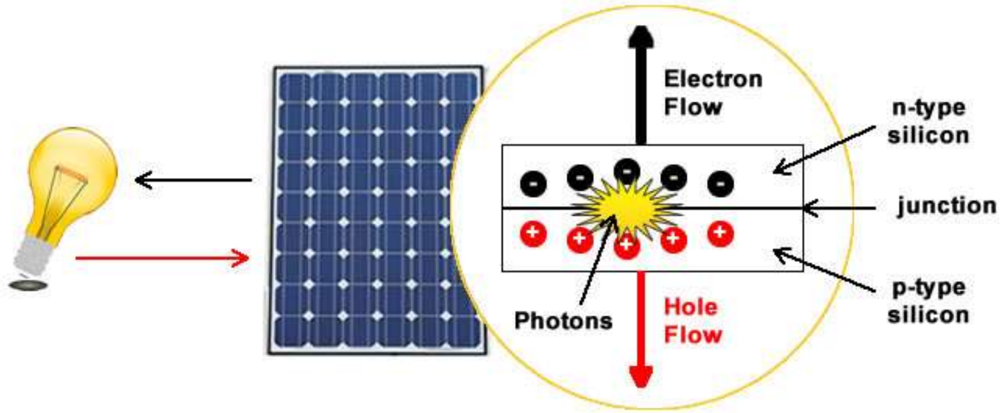
OUTLINE

- Introduction
- How Solar Cells Work
- Different Types of Solar Cells
- How Solar Cells Are Made
- How Solar Panels Are Made
- Types Of Solar PV Systems
- Types Of Solar Hot Water Systems
- Things To Keep In Mind
- Advantages Of Solar Energy
- Other Uses Of Solar Cells

INTRODUCTION

A solar cell is an electrical device that converts energy of the light into electricity by the photovoltaic effect. These solar cells are combined to form a solar panel which are used today to help homeowners or commercial businesses save money. Throughout this E Book we will be covering the structure of these cells and how they can be converted into power which can operate numerous appliances.

HOW SOLAR CELLS WORK



The solar cell works in three steps:

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.

2. Electrons (negatively charged) are knocked loose from their atoms, causing an electric potential difference. Current starts flowing through the material to cancel the potential and this electricity is captured. Due to the special composition of solar cells, the electrons are only allowed to move in a single direction.

3. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

Photovoltaic Cells

Converting Photons to Electrons - The solar cells that you see around your environment are called photovoltaic (PV) cells, which as the name implies (photo meaning "light" and voltaic meaning "electricity") convert sunlight directly into electricity. The operation of a photovoltaic cell requires 3 basic attributes:

1. The absorption of light, generating either electron pairs or excitons

2. The separation of differing types of charge carriers

3. The separate extraction of those carriers to an external circuit

A module is a group of cells connected electrically and packaged into a frame (more commonly known as a solar panel), which can then be grouped into larger solar arrays.

Photovoltaic cells are made of special materials called semiconductors such as silicon, which is currently used most commonly. When light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This allows the energy of the absorbed light to be transferred to the semiconductor.

PV cells also 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 for external use. This current, together with the cell's voltage, defines the power that the solar cell can produce.

The Use Of Silicon

Silicon has some special chemical properties, especially in its crystalline form. An atom of silicon has 14 electrons, arranged in three different shells. That's what forms the crystalline structure, and that structure turns out to be important to this type of PV cell.

When energy is added to pure silicon, in the form of heat for example, it can cause a few electrons to break free of their bonds and leave their atoms. This process gives the resulting silicon an N-type ("n" for negative) charge because of the prevalence of free electrons. N-type silicon is a much better conductor than pure silicon. Instead of having free electrons, P-type ("p" for positive) has free openings and carries the opposite (positive) charge.

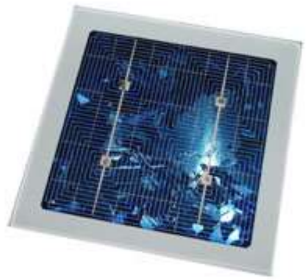
This process of the P-type and N-type charges provides and electric field which acts as a diode (pushing P to N and not the other way around). The electron flow provides the current, and the cell's electric field causes a voltage. With both current and voltage, we have power, which is the product of the two.

Since Silicon is very shiny, photons have the tendency to leave before this process is complete. This is why an anti-reflective coating is applied to reduce those losses. The final step is to install something that will protect the cell from the elements often a glass cover plate.

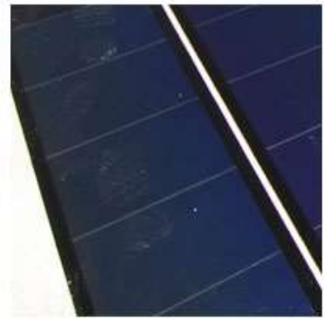
PV modules are generally made by connecting several individual cells together to achieve useful levels of voltage and current, and putting them in a sturdy frame complete with positive and negative terminals.

DIFFERENT TYPES OF SOLAR CELLS

Monocrystalline



Polycrystalline



Thinfilm

There are three main types of solar cells, which are distinguished by the type of crystal used in them.

1. Monocrystalline solar panels – the most effective cells/ panels when absorbing light and converting it into energy. These panels are made up of large silicon crystals but are very expensive but do better in lower light conditions. This cell works best on a south-facing roofs with minimal shade. However this solar cell still performs well under low light conditions. Monocrystalline silicon panels typically have a warranty of 25 years , meaning the initial higher cost is earned back.

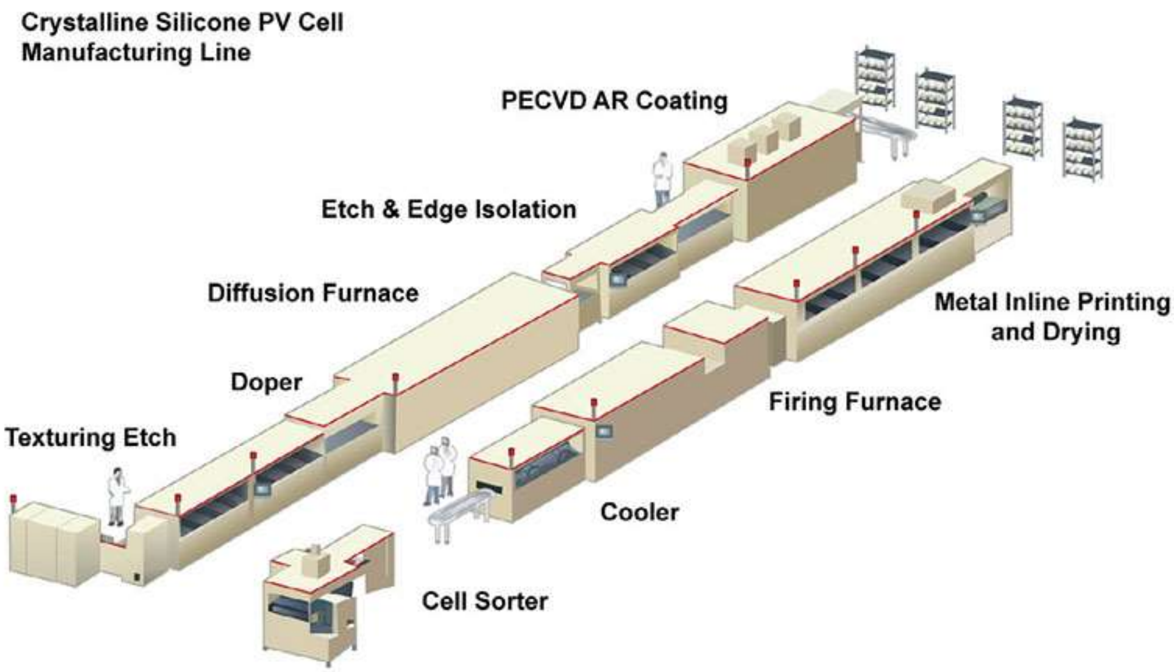
2. Polycrystalline solar panels – the most common cells/panels on the market today. They look like pieces of shattered glass . Although these panels are less efficient then the monocrystalline, this is because instead of one large crystal these contain mutlitple smaller crystals making it look like shattered glass. Polycrystalline cells can be recognized by a visible grain, a “metal flake effect”. Polycrystalline solar panels have higher heat tolerance than those made of monocrystalline silicon. These solar panels also come with a the same warrant of 25 years.

3. Amorphous solar panel – consists of a small layer of melted silicon which is spread across plates of stainless steel or glass. Their great advantage lies in their relatively low cost per watt of power generated. This solar cell has the shadow protected layer which ensures that even if the panel is in the shade or shadown of another object, it still is able to charge which is sometimes used on transportation. The efficiency of amorphous solar panels is not as high as those made from the solar cells above but is the least expensive of three.

	Monocrystalline	**Polycrystalline**	**Amorphous**
Efficiency (Direct Light)	~ 12%	~ 12%	~ 6%
Efficiency (Low Light)	Medium	Low	Proportional to shaded area

Efficiency (High Temp)	Reduced 12-15%	Reduced 14-23%	No Reduction
Cost / Watt	High	Med – High	Med
Portability	Rigid / Low	Rigid / Low	Flexible / High
Reliability	High	Med – High	Med

HOW SOLAR CELLS ARE MADE



1. Purifying the Silicon - The silicon is placed inside of a furnace to release all the oxygen. This process is repeated until the silicon is considered “pure” and is then removed.

2. Making Single Crystal Silicon - Solar cells are made from silicon boules, polycrystalline structures that have the atomic structure of a single crystal. The most commonly used process for creating the boule is called the Czochralski method. In this process, a seed crystal of silicon is dipped into melted polycrystalline silicon. As the seed crystal is withdrawn and rotated, a cylindrical ingot or "boule" of silicon is formed.

3. Making Silicon Wafers - From the boule, silicon wafers are sliced one at a time using a circular saw whose inner diameter cuts into the rod, or many at once with a multi-wire saw. Rectangular or hexagonal wafers are sometimes used in solar cells because they can be fitted together perfectly, thereby utilizing all available space on the front surface of the solar cell. The wafers are then polished to remove saw marks.

4. Doping - The wafers are then sealed back to back and placed in a furnace to be heated to slightly below the melting point of silicon in the presence of phosphorous gas. The phosphorous atoms "burrow" into the silicon, which is more porous because it is close to becoming a liquid. The temperature and time given to the process is carefully controlled to ensure a uniform junction of proper depth.

5. Placing Electrical Components - Electrical contacts connect each solar cell to another and to the receiver of produced current. The contacts must be very thin so as not to block sunlight to the cell. The cells are encapsulated in ethylene vinyl acetate and placed in a metal frame that has a mylar backsheet and glass cover. After the contacts are in place, thin strips are placed between cells. The most commonly used strips are tin-coated copper.

6. The Anti-Reflective Coating - Because pure silicon is shiny, it can reflect up to 35 percent of the sunlight. To reduce the amount of sunlight lost, an anti-reflective coating is put on the silicon wafer. The most commonly used coatings are titanium dioxide and silicon oxide, though others are used. The material used for coating is either heated until its molecules boil off and travel to the silicon and condense, or the material undergoes sputtering.

7. Encapsulating the Cell - The finished solar cells are then encapsulated; that is, sealed into silicon rubber or ethylene vinyl acetate. The encapsulated solar cells are then placed into an aluminum frame that has a mylar or tedlar backsheet and a glass or plastic cover.

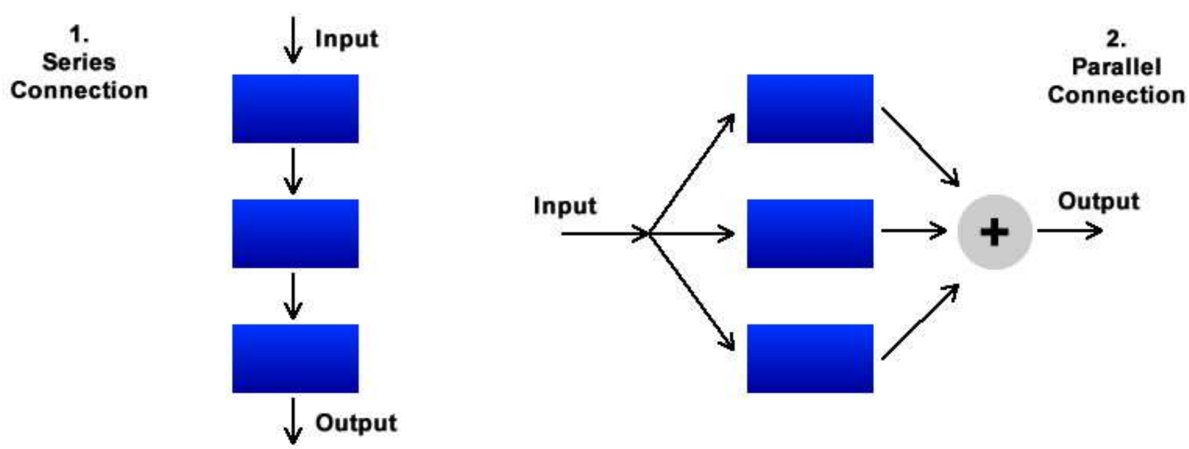
8. Cooling – After the coatings are applied to the cell, cooling is needed to decrease the temperature in order to inspect the products.

HOW SOLAR PANELS ARE MADE

From the manufacturing process above, there are two basic connections in which can be used to combine these cells into panels.

- Series Connection (a) – a connection of multiple single solar cells combined into a group. The output of the series string is equivalent to the current of a single cell but the voltage output is increased, a combination of all the cells combined within the group.

- Parallel Connection (b) – Again when making a group of individual cells combined, the voltage and current are switched. The current is now the addition of all the currents within the group while the voltage stays the same as in one cell.



TYPES OF SOLAR PV SYSTEMS

Off-Grid Solar System

Grid-Tie Solar System

Grid Tie

Grid Tie systems are the most common method of installing a residential solar powered system. These panels are connected to the pain power grid and are designed to sell power back to the utility company known as net metering.

When these systems produce a DC electric current the grid tie converter changes it into AC so it can be used inside the home or sold back for a profit.

- These kits usually contain:
    - PV wiring
    - PV converter
    - Grid Tie Solar Panels
    - AC-DC inverters
    - Mounting hardware

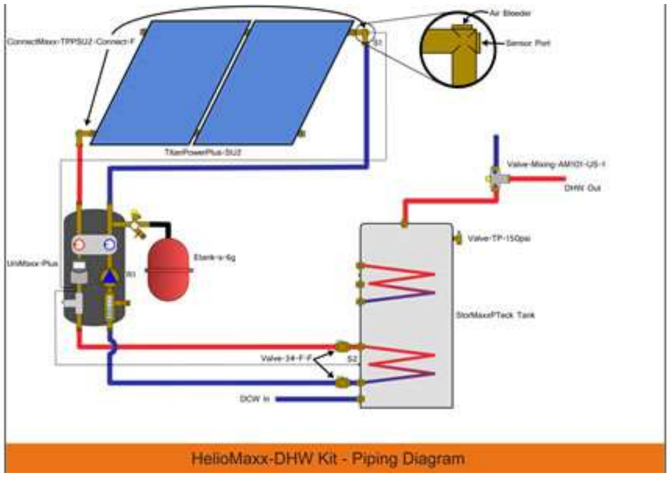
Off Grid

Off-grid systems are generally larger than grid-tie systems. To be fully independent, a system must have a greater array of energy-producing panels, which in turn requires more batteries to store the charge and more equipment to regulate the charge.

DC Power – such as RV's, boats, and cabins, as well as farm/ranch appliances like cattle gates and rural telecommunications systems need DC power to operate. DC is less expensive then AC, because solar panels don't store electricity and only generate power during daylight hours, off-grid power works by storing solar power in a deep-cell battery or bank of batteries. Usually comes with a disconnect switch, so if there is any needed repair you can safely work on the panels.

AC Power – just like DC is connected the same way however, there is an inverter which changes the current since it comes in as DC. This needs to be accomplished because AC is the standard form of electricity new appliances and a modern house operates on AC power. This is more expensive then DC power however is more modern for its use.

TYPES OF SOLAR HOT WATER SYESTEMS



Solar Hot Water Systems, also known as Solar Thermal Systems (STS) operate differently from photovoltaic (PV) systems. Solar thermal systems run water or fluid through their system. The solar panels are heated and the water running through them gets heated, so the water is ready for use.

Solar hot water systems are environmentally friendly and can now be installed on your roof to blend with the architecture of your house. More than 1.5 million homes and businesses in the United States have invested in solar heating systems.

Most solar water heaters require a well-insulated storage tank. Solar storage tanks have an additional outlet and inlet connected to and from the collector.

Heating Systems

Active System – As shown in the picture, there is a pump within the system which circulates water throughout which will reduce up to 90% of heating costs.

- Direct Circulation System – the system pumps water directly into the solar collectors and through the house. Also known as the open loop active system

- Indirect Circulation System – instead of the heated water moving through the system, this unit needs a heat exchanger in order to pump heat transfer fluid throughout. Also known as a closed loop active system, usually only used for multiple uses of the water that is heated such as a pool and hot water.

Passive System – does not use a pump to circulate water, it uses convection, less expensive to install, may not be the most efficient but is the most reliable and lasts longer than the active, only can reduce water heating up to 75%.

	Warm Climate	**Moderate Climate**	**Cold Climate**
Appropriate System	Passive System	Active (Closed Loop)	Active Systems
Benefits	Easy to install No moving parts Uses no electricty, will function during blackouts	Pumps, valves, and controllers assist in preventing freezing Uses electricity, will not function during blackouts	Heavy-duty residential and commercial
Location	USA (except northern Midwest)	USA (except northern Midwest and some southern states)	USA (northern Midwest and northeast)

Solar Collectors

Three types of solar collectors are used for residential applications:

1. Flat-plate collector - Glazed flat-plate collectors are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers. Unglazed flat-plate collectors typically used for solar pool heating have a dark absorber plate, made of metal or polymer, without a cover or enclosure. This solar collector looks like the solar panels in most of the pictures above.

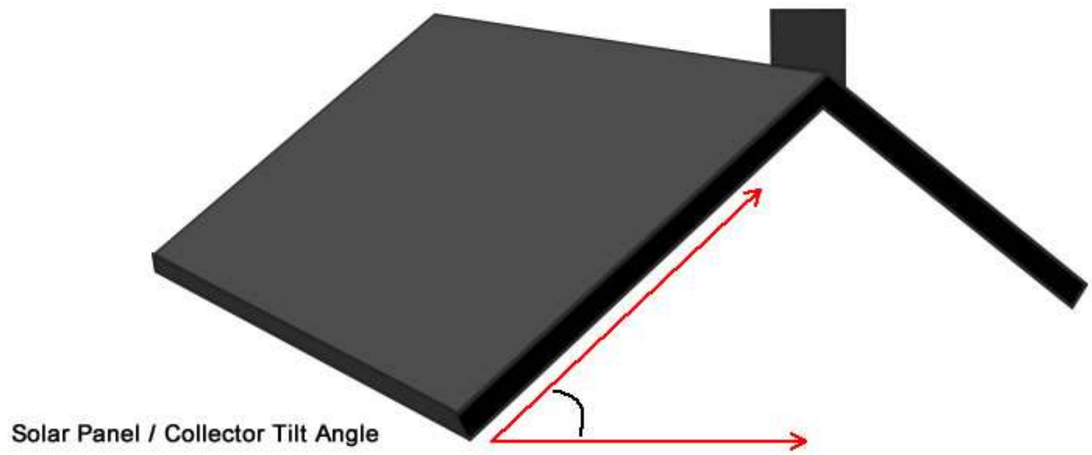
2. Integral collector-storage systems - Also known as ICS or batch systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.

3. Evacuated-tube solar collectors - They feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for U.S. commercial applications.

Evacuated Tube Collector Components

THINGS TO KEEP IN MIND

Tilt Angle



The orientation of the panels will ultimately result in the intensity and amount of rays your unit can absorb based on the sun. Tilt angle is the angle in which is the angle between the plane of the module and the horizontal.

The optimum angle will depend on the latitude which the unit is placed. When the latitude is small the maximum angle is the latitude angle while the array facing due south. For higher latitudes the maximum angle is the latitude angle minus roughly 10-15 degrees. This output will give the maximum value over the course of a year but changing weather patterns could alter this number.

Maintenance

There is little to no maintenance needed after mounting the panels other than cleaning once and a while to make sure optimum exposure. Also there may be a need to cut back trees or branches which could be interfering with sunlight.

Advantages of Solar Energy

- Low maintenance
- Clean
- Economical
- Up to 30% in tax deductions

OTHER USES OF SOLAR CELLS

Solar Impulse Plane

Solar Cell Phone Chargers

Solar Powered Satellites