Basics of Solar PV Energy

Solar Energy 101

BIRTH OF THE PV CELL

Solar History

We can trace all energy used on our planet back to the source...the nearest star, our sun. The history of solar energy is as old as humankind. In the last two centuries, we started using Sun's energy directly to make electricity.

In 1839, Alexandre Edmond Becquerel (pictured on the left) discovered that certain materials produced small amounts of electric current when exposed to light.

William Grylls Adams, who, with his student, Richard Evans Day, discovered in 1876 that a solid material - selenium - produced electricity when exposed to light. Selenium photovoltaic cells were converting light to electricity at 1 to 2 percent efficiency.

Photovoltaic, or PV for short, is the word that describes converting sunlight into electricity: photo, meaning pertaining to light, and voltaic meaning producing voltage. It took, more than 100 years, however, for the concept of electricity from sunlight to become more than an just an experiment.

<u>Birth of the PV Cell</u>

In 1954, D.M. Chapin, C.S. Fuller and G.L. Pearson, of Bell Laboratory, patented a way of making electricity directly from sunlight using silicon-based solar cells.

The next year, the Hoffman Electronics-Semiconductor Division announced the first commercial photovoltaic product that was 2 percent efficient, priced at $25 per cell, at 14 milliwatts each, or $1,785 per watt (in 1955 dollars).

By the mid-1960s, efficiency levels were nearing 10 percent. As an outgrowth of the space exploration in the 1960s-70s, PV development increased dramatically. But world wide hostilities and the threat of war turned the world more and more away from oil and toward renewable energy.

SOLAR ELECTRICITY TODAY

We can change sunlight directly to electricity using solar cells. Every day, light hits your roof's solar panels with photons (particles of sunlight). The solar panel converts those photons into electrons of direct current ("DC") electricity. The electrons flow out of the solar panel and into an inverter and other electrical safety devices. The inverter converts that "DC" power (commonly used in batteries) into alternating current or "AC" power. AC power is the kind of electrical that your television, computer, and toasters use when plugged into the wall outlet.

A net energy meter keeps track of the all the power your solar system produces. Any solar energy that you do not use simultaneous with production will go back into the electrical grid through the meter. At night or on cloudy days, when your system is not producing more than your building needs, you will consume electricity from the grid as normal. Your utility will bill you for the "net" consumption for any given billing period and provide you with a dollar credit for any excess during a given period. You can carry your bill credit forward for up to a year.

PV systems today can be blended easily into both traditional and nontraditional homes, powering appliances and electric systems. PV cells can be installed as a stand-alone module that is attached to your roof or on a separate system, or using integrated roofing materials with dual functions - that as a regular roofing shingle and as a solar cell making electricity. The most common practice is to mount modules onto a south-facing roof or wall. PV systems likewise can be blended into virtually every conceivable structure for commercial buildings. You will find PV used outdoors for security lighting as well as in structures that serve as covers for parking lots and bus shelters.

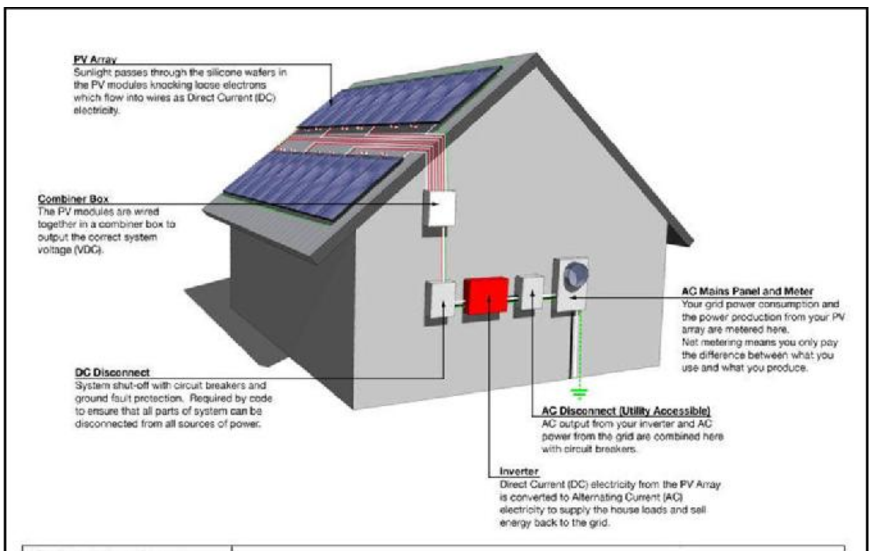
A photovoltaic (PV) system needs unobstructed access to the sun's rays for most or all of the day to be effective. Shading on the system can significantly reduce energy output. Climate is not a major concern because PV systems are relatively unaffected by air temperatures, and snow cover typically melts quickly because panels are positioned directly into the sunlight. Abundant year-round sunshine makes solar energy systems useful and effective nearly everywhere in the USA.

SOLAR PHOTOVOLTAIC (PV) SYSTEM

Solar cells are small, square-shaped panel semiconductors made from silicon and other conductive materials, manufactured in thin film layers. When sunlight strikes a solar cell, chemical reactions release electrons, generating electric current. Solar cells are also called photovoltaic cells or "PV cells" and can be found on many small appliances such as calculators.

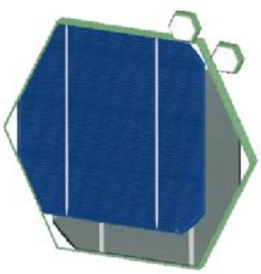
A PV system components include PV modules (groups of PV cells), which are commonly called PV panels; one or more batteries; a charge regulator or controller for a stand-alone system; an inverter to covert solar power from direct current (DC) to the alternating current (AC) of the utility grid-connected system; wiring; and mounting hardware or a framework. A PV module arranges individual PV cells, and the modules are grouped together in an array. Some of the arrays are set on special tracking devices to follow sunlight all day long and improve system efficiency.

There are two types of solar inverters – string inverter and micro-inverter. String inverters have dominated the solar industry since its inception. The introduction of micro-inverters marks one of the biggest technology shifts in the PV industry to date. Manufacturers are touting 5-25% increase in power output, which in the long run can bring in a lot in savings for many homeowners.



Grid-Tie System

SILICON SOLAR CELL



How Does Silicon Produce Energy?

Silicon is the most common conductor used in PV cells nowadays, for several reasons. The main reasons lie in the extremely low price of silicon and the fact that it's widely available worldwide.

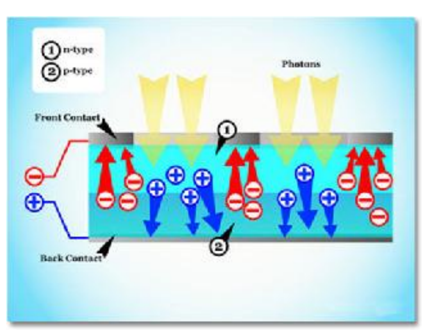
However, pure silicon is not an excellent conductor due to its crystalline structure. A silicon atom has 14 electrons in three different layers (or shells), with 2 electrons in the first, 8 in the second, and 4 in the third layer.

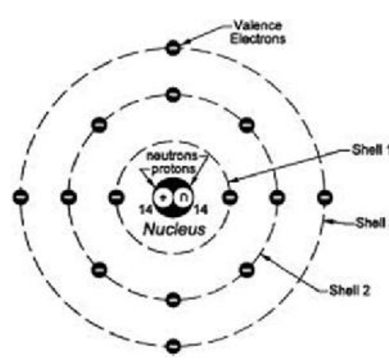
This third layer is only half full and the atoms always seek to fill up their layers with electrons by sharing them with other atoms around them.

However, because of the even number of electrons, each silicon atom will have a full share, which leaves less room for free electrons to go. When energy is added to silicon, some of these electrons break free and look for holes left by other free electrons.

This movement of electrons is what actually generates electricity. The photons strike the PV cell and ideally, each photon will knock one electron free and send it searching for a hole to fill, thus conducting electricity. Because silicon has an even number of electrons, all modern solar cells use impure silicon as a way to free up extra electrons to conduct energy better.

All solar companies have a patented crystalline structure that they use in their own panels, and these are made by adding other atoms into the silicon, although usually only a few parts per million. The two main types of atoms that are added to silicon to form solar cells are usually phosphorous and boron.





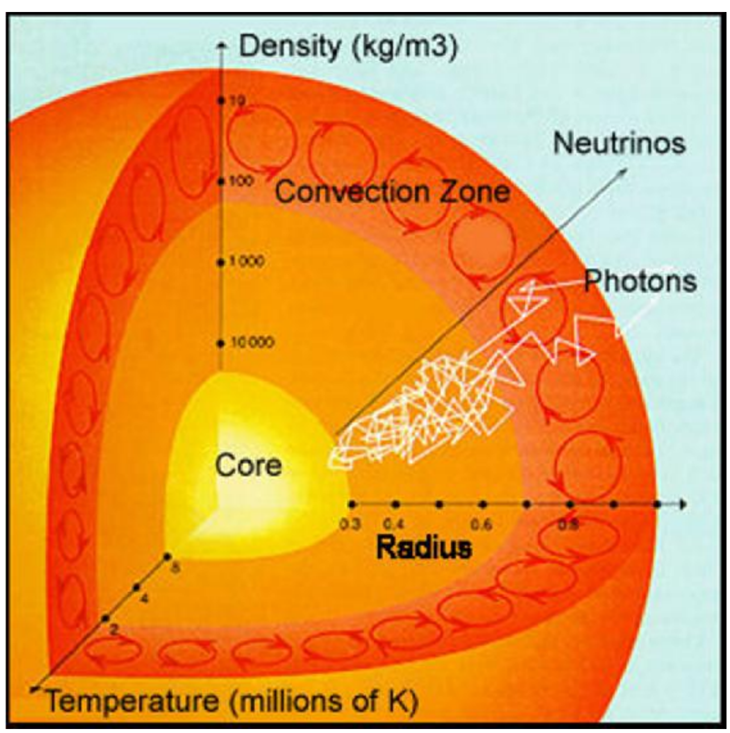
HOW DOES SOLAR POWER WORK?

Part 1- The Sun as Energy Creator

Most people understand that the sun gives life to all things on this planet through its light and heat, but the sun also produces many other things. The process of solar energy began in the center of the sun, almost a million years ago. Photons are created through the fusion of atoms in the sun's core. They will eventually be what generates solar power, but not until they are able to escape from the sun.

It generally takes a photon over a million years to escape from the center of the sun to the sun's surface. Once at the surface, the photons are sent hurtling out into space in all directions, and some of them are aimed directly at the Earth.

The photons are sent out at such an incredibly fast speed, that the ones which reach Earth travel over 93 million miles in under 8 minutes. They are basically tiny packages of sunlight, also known as quanta - which is where the term quantum mechanics comes from.



HOW DOES SOLAR POWER WORK?

Part 2- Converting Photons into Energy

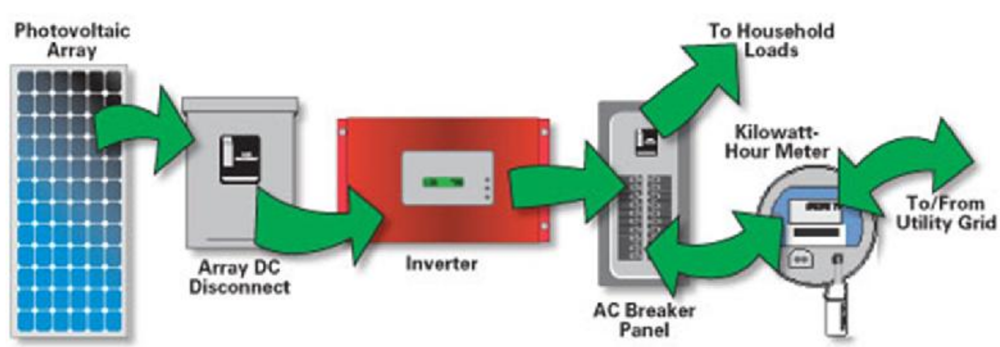
Once the photons reach Earth, we must harness them in order to create electricity from them. This is done through the use of photovoltaic cells which react with the photons. These PV cells are coated with a material - usually silicon in most modern cells - which displays the photovoltaic effect.

The photovoltaic effect is used to describe the process in which energy is created by certain materials when they are exposed to solar radiation or sunlight. This process was first discovered by the French scientist Alexandre-Edmond Becquerel in the mid 1800's. These PV cells are stimulated by sunlight and then produce direct current electricity. However, this energy must still be made useable.

Part 3- AC/DC

No, not the band. Most all appliances and electronics use alternating current or AC power, which differs from the direct current or DC power that is generated by solar panels. In order to transform this DC power into AC power, it is necessary to have a solar power inverter connected to your solar panels. This inverter allows the energy generated to be consumed, fed back into the grid, or used to charge a battery depending on what type of solar energy generating unit you have.

Diagram – Most common Grid-tie Solar System



HOW DOES SOLAR POWER WORK?

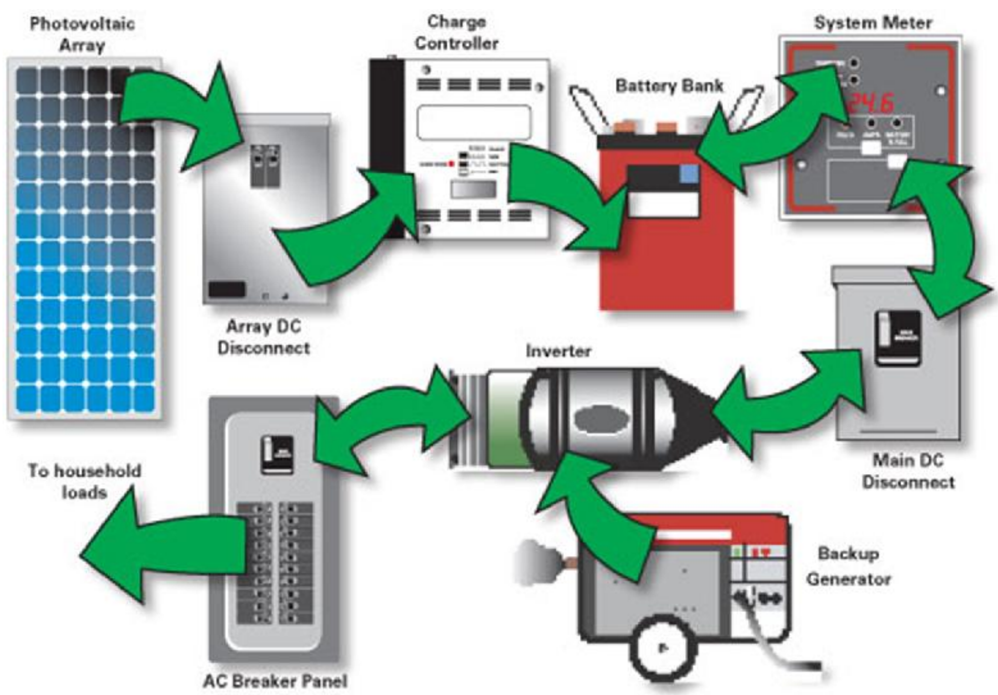
Solar Power

Part 4- Solar Energy Consumption and Storage

Once the solar energy is converted into AC power, it is possible to use this energy to power your home or business. If you have a grid tie solar system, the electricity you produce will be fed directly back into your local power grid. When you are producing electricity, any energy you consume will come directly from your solar system and any excess will go back into the grid.

When you are not producing electricity, then any electricity you consume will come directly from the power grid. If you have an off-grid solar system, then your system will have a rechargeable battery in the loop, right after the inverter. This battery is charged by your solar cells and stores any excess energy, which guarantees that you will always be using the energy you generate yourself, and that you'll always have energy as long as you produce sufficient amounts.

Diagram – Off Grid Solar System with rechargeable batteries



WATTS & KILOWATTS & KWH... OH MY!

A watt (W) is a measure of POWER (or one joule per second). Power is the rate at which energy is used per unit time (an indicator of how fast an item uses energy). A kilowatt (kW) is, simply, one thousand watts, just as a megawatt (mW) is one million watts. When we're talking about electricity, power is voltage times amperage or 1 watt = 1 volt x 1 ampere.

True, this may sound a bit like your high school physics class, but don't panic. Read on and you'll see it's a simple concept to grasp...

One of the easiest ways to think about all of this is to think of electricity as water coming out of a hose. Voltage is the water pressure and the amperage is the flow. When there's a kink in your garden hose, there's a lot of pressure (voltage), but the water is not flowing anywhere (no amperage), which means there's no power (i.e. a lot of volts x zero amps = zero watts).

Now let's take this understanding and apply it to what happens when we un-kink the hose, and the water comes rushing out of it. The result is, a lot of volts x a lot of amps = huge POWER.

Okay, so you've got the concept POWER down, let's go back to watts (W). A watt (W) is energy burned per second. A 100-watt light bulb eats up 100 joules of energy every second. Since "watts per hour" doesn't make sense, because it's already measuring "joules per second" and thinking of "joules per second per hour" is enough to make most people's eyes glaze over, our utility companies use a watt-hour to charge us for the electricity we use. It's a way of removing "per second" from watts.

Now let's use one more analogy to wrap up this explanation – pretend you're running a marathon. Think of watts as the speed you're running (i.e. the rate of energy used in that instant), and watt-hours as the total amount of energy you've used while running at a certain rate over an hour.

WATTS & KILOWATTS & KWH… OH MY!

A kilowatt-hour (kWh) is the amount of energy equivalent to powering one kilowatt (kW) for one hour. A kilowatt hour (kWh) is a unit of ENERGY that is a much more convenient unit to use rather than the kilo-joule. It represents the power used by the appliance multiplied by the hours in use. In other words, when you leave a 100-watt lightbulb on for 10 hours you've used a kilowatt-hour (kWh) of energy and the energy provider (TEP) will bill you accordingly.

So, as you can see, the kW and kWh are fundamentally different. Appliances show their power ratings (kW) on the nameplate to give you an idea of how much energy is used per second by the item. At EcoOne, we look at the amount of kWh on your utility bill to find out how much energy your home or business uses so that we can recommend the size solar PV system that would best suit your needs.

For Example:

Solar systems are generally sized in 1 kW – 9 kW (and larger) systems. A typical size is 3 kW. (3 kW, or 3 kilowatts = 3,000 watts). A 3 kW system will generate around 3,000 DC watts per hour

Multiply the per hour generation by 5.4 which is an average number of sun hours in a day (3,000 x 5.4 = 16,200)

Multiply the new total by the average number of days in a month (16,200 x 30.5 = 487,620)

Multiply the new total by .77. This is the "derating" factor, or the amount of energy lost when DC current is turned into AC current. (487,620 x .77 = 375,467). So, a 3 kW system will generate about 375,467 watt-hours per month, or about 375 kWh.

Now compare this number with the kWh usage noted in your electric bill. How many kWh do you use in a typical month? Twice this amount? Then you would save roughly ½ your electric bill if you installed a 3 kW system.

WATTS & KILOWATTS & KWH… OH MY!

Electric Power

Another way to look at the math – in reverse:

If you want to get all of your energy needs met through solar power (and get a "Zero" bill from TEP) calculate how large a system you will need by following the steps below.

Before you start, choose an **average** electric bill. Look for how many "kilowatt hours" AC you consumed. This is generally expressed as "kWh" AC.

For Example: (Just for FUN)

- Note the average number of kWh you use per month = 550 kWh AC
- kWh X 1000 = total AC Watts used per month = 550,000
- Total AC Watts / 30.5 (days in a month) = AC Watts used per day = 18,033
- AC Watts used per day / Sun Hours per day (Central Texas = 5.4) = AC Watts needed per hour per day = 3339
- AC Watts needed per hour per day X 1.29 (AC to DC conversion factor) = 4307
- Solar array in DC Watts to reach a Zero electric bill = 4307 Watts DC
- Solar array in kilowatts, or kW = DC Watts/1000 = 4.3 kWatts DC

Your Information: (No Worries if you see a plus sign and you faint, we do all the calculation for you. Contact us for a free solar energy audit.

Description	Example	Your Info
Average kWh AC per month =	550	
kWh AC X 1000 =	550 X 1000 = 550,000	
AC Watts/month / 30.5 days =	550,000 / 30.5 = 18,033	
AC Watts used/hr/day / Sun hrs/day (Austin, TX = 5.4) =	18,033 / 5.4 = 3339	
AC Watts needed/hr/day X 1.29 (AC to DC conversion factor) =	3339 X 1.29 = 4307	
Solar Array in DC Watts for a "Zero" Bill per month =	4307	
Solar Array in kiloWatts or kW =	4307 / 1000 = 4.3 kW	