SOLAR FUNDAMENTALS

A primer on
solar electric systems
for Ecopreneurs

POWUR of citizenrē

Contents

Preface

Solar Fundamentals

This training is designed to give you a fundamental understanding of the photovoltaic industry. It is not intended to not make you a solar "expert." There will always be people with more information than you. If you claim to be an expert, they will poke holes in your arguments and try to tear you down.

Your role is service

The role of an Ecopreneur is always one of *service*. When you have completed this training, you will be able to provide better solutions and support to your prospects and customers.

The more information you have, the more confident you will be—not an arrogant confidence like we-are-the-best-and-no-one-else-has-anything-of-value—but an *inner assurance* that you have a deeper understanding of a solar service that will help your customers and our planet.

You will rarely be asked much of the information covered in this training, but your inner confidence will put your prospects and customers at ease and make the whole process more enjoyable.

When you meet an "expert"

A few people may attempt to poke holes in your knowledge. You can usually sense their intent immediately because their tone and energy is attacking rather interested. Often it is best to just let them be right and compliment them. A great response is, "You seem to know a lot about the solar industry. What is your background?" Listen and be impressed. People love to talk about themselves.

We're changing the landscape

There are many dedicated people in the solar industry and some can feel threatened by our model. Citizenre changes the landscape of an industry they have spent years understanding. It is like putting a sailor who has been at sea for months back on solid land. Though their future is more stable, it takes some time for them to become comfortable.

Ambassadors for Positive Change

Our job is to be ambassadors for positive change in the world of renewable energy. We must be respectful of the important work that has been done before us and offer a clear picture of our unique solution as we lead the industry to success imagined by only the few.

Phillips Brooks said,
"Do not pray for easy lives.
Pray to be stronger men and women.

Do not pray for tasks equal to your powers.
Pray for powers equal to your tasks."

Rob Styler, July 2007

1 The Magic of Solar Energy

Electricity is Magic!

Sales Relevancy:
Through out this module you will find notes about sales relevancy. These tell you how the technical data you are learning can be simplified and demonstrated for a sales presentation.

Our customers do not need to know everything in this module, but they do need to know that you do and that you are a confident and qualified person to guide them on their renewable energy needs.

As the wizards in the Harry Potter series put it, "Electricity is what muggles use in place of magic."

Popular physics author Kenn Amdahl writes in his book, **There Are No Electrons: Electronics for Earthlings**, "Some people honestly believe they understand electricity, just as alchemists once thought they understood how to transform lead into gold..."

Nevertheless, as Amdahl points out, we do know how electricity works and the principles that govern its functionality in our modern world. In this training you will learn the basics about solar electricity and the systems that produce it. However, even in the midst of all the important principles and technical jargon, please do not lose sight of the magic. We are putting crystals on people's roofs that turn sunlight into usable electricity. This is amazing!

To understand solar energy systems you first need to understand the basic principles of electricity. This means learning the language used to explain these principles, and the language of solar electric systems. Become comfortable with the jargon so you feel comfortable talking with industry experts and peers. But at the same time learn how to convey the *simple* version for when you are talking with your residential customers.

Why you should know this stuff

The best sales people know their product and industry completely. This gives them the confidence to make recommendations to their customers. More importantly, it gives their customers confidence that they are dealing with the right person in the right company at the right time. The best sales people are not even considered sales people—they are thought of as consultants.

It is the goal of this module to educate renewable energy consultants who can confidently answer most of our customers' questions. You should be able to compare Citizenre's product and services with other products and services in the PV industry and demonstrate why our solution is most appropriate for the customer. You can also explain why this is the best time to get in and join the solution with Citizenre.

You are not selling solar systems—you are helping people join the solution.

Solar Competency Test

When you have finished reading this training and reviewed appropriate sections in the Introductory training (Modules 2 and 3) and the Manager's training (Module 2), you can take the Solar Competency Test.

When you have passed this test, you will be eligible to receive leads from the Cooperative Marketing Partners, who often will have a greater knowledge of solar than the average homeowner.

2 Electricity Fundamentals

Demystifying Electrical Jargon

Sales Relevancy:
It is important for you to know the specific meaning of electrical and solar terms if you want to be credible to your more savvy customers.

They will be talking about watts and kilowatts, inverters and module types. You want to be able to answer their questions.

If you aren't an electrician or electrical engineer, you may find terms for electricity a bit confusing. The purpose of this chapter is to help you to understand enough about electricity that you can understand the concepts used with photovoltaics.

You will review a lot of concepts and terms that you need to be able to use correctly. You may find that they mean something different than you thought.

When you start talking about solar systems, or even your electric bill, you hear a lot about kilowatts and kilowatt-hours. You may have used them interchangeably, because they are just a measure of relative size. However, they are very different measurements, as you will learn here.

In order to understand what they mean, you also need to understand a few basic concepts about electricity.

Please also refer to the extensive glossary in the **Powur of Citizenre Manager's Training, Module 2: Photovoltaics and REnU**.

Electrical concepts

When talking about electricity, you will be using terms like **power** and **energy**, which we often use interchangeably in daily speech, as well as **current**, **potential**, **charge**, **electrons**, and even

photons. You might have learned about all of these in high school physics, but usage in daily life may have confused their meaning.

Here are the most important concepts you need to know. You may be surprised that their meaning is not quite what you expected.

Power. The *rate at which work is performed* or energy is supplied, or the amount of energy required or expended for a given unit of time. It is measured in **watts (W**.)

Energy. The actual *work* done, for example by solar panels, in other words, *power over a period of time*. It is typically measured in **joules** or (in the electric business) **watt-hours (Wh**.) Energy is defined in many ways, depending on which science you are talking about. In popular speech, energy and power are confused. (*I have a lot of energy today...*)

Potential. The *capacity* of an electric field *to do work (provide energy,)* like the height of water behind a dam (the higher the water, the more energy available). It is measured in **volts** (**V**).

Current. A movement or *flow of electrically charged particles*, like the speed of water flow in a river. It is measured in **amperes** (**I** - *aka* “amps”).

Resistance. The property of a material, object or circuit to resist the flow of electricity. Materials that allow electricity to flow easily (with low resistance) are called **conductors**; materials that resist the flow of electricity are called **insulators**. It is measured in **ohms** (**R**.)

Charge. A property of some subatomic particles, which determines how they interact. Electrically charged matter is influenced by, and produces, electromagnetic fields. Charges are **negative** (as for electrons) or **positive** and have measurable strength.

Field. An *effect produced by an electric charge* that exerts a force on charged objects in its vicinity.

Electron. A negatively charged subatomic particle. The current is caused by the movement of electrons.

Photon. An elementary particle that is the carrier of electromagnetic radiation of all wavelengths. The photon is different from many other elementary particles, such as the electron, because it has no mass. That means that it travels (in vacuum) at the speed of light. You will read more about photons in the next chapter.

Note: *Light has both wave and particle properties.*

- *As a **wave**, light is distributed over space and can be refracted by a lens; reflected waves can cancel each other out (called "destructive interference.")*
- *As a **photon particle**, it interacts with matter by transferring energy.*

Units to measure electricity

Watt. The basic unit to measure **power** with electricity, just like horsepower is used to measure the power of cars. (1 hp is about ¾ kW.) A watt can be defined with this equation:

watts = volts x amps (W = V x I)

Volt. The unit of "potential difference" or "electromotive **force**" (or pressure.)

volts = amps x ohms (V = I x R)

Ampere (amp). The unit of electic **current**.

amps = volts / ohms (I - V / R)

Ohm. The unit of electrical resistance.

ohms = volts / amps (R = V / I)

Kilowatt. Solar electric systems are sized and referred to in *kilowatts* (kW), which is a measure of the **power** available in the system, in other words, how much energy can be produced by the system at any given instance under optimal circumstances.

Kilowatt hours. To measure **energy** (which is also known as **work**, or **output**) you need a *timeframe* together with the amount of *power* available.

Utility companies use *hours* as the time factor and *kW* as the unit of electricity. So they bill customers in kilowatt-hours (kWh).

Likewise, a 1 kW solar array in direct sun for one hour will produce 1 kWh energy to do work, like lighting a 100 W lightbulb for 10 hours.

Comparing electricity to water

If we liken electricity to water running through a pipe

- Watts (power) measures the amount of water at the end of the pipe at any single point in time
- Volts (force) measures the water pressure
- Amperes (current / rate of flow) measures the volume of water flowing by a point

So if you take the rate of water flow (amps) times the pressure (volts) you would get the amount of water (watts) at the end of the pipe at any given instant.

The comparison with a measure of **energy** would be the quantity of water to, say, fill a bucket. This is equivalent to the *amount* at the end of the pipe times the *time* it takes to fill the bucket. So a kWh is like a bucket full of water (*watts*) filled *in a given time period (hours)* using enough water flow (amps) with enough pressure (volts).

Watts or kilowatts?

A watt is a unit of power, which when multiplied by time gives you a measure of the energy which does work, like keeping our lights on, powering our computers and running motors, like for pumps or the air conditioner.

Watts are really small and are used to describe the potential energy production of a single solar cell (around 3 watts) or single solar module (around 100-200 watts).

When we talk about usable amounts of energy, we use the measure kilowatts (kW) or 1,000 watts. Utility companies measure residential power *consumption* in kWh and residential solar arrays are measured in kW, for the power they can produce.

These conversions might be helpful when you are talking about very large installations.

- One kilowatt (kW) is one thousand watts (10^3 watt) - households
- One megawatt (MW) is a million watts (10^6 watt) - industrial systems
- One gigawatt (GW) is a billion watts (10^9 watt) - solar manufacturing plant output.
- One terawatt (TW) is a trillion watts (10^{12} watt)

How many kWs for a solar array?

Think of a customer's power consumption as a bucket of water and the amount of solar radiation as the time they need to fill that bucket. Then it is easier to understand how to size the solar array to meet the customer's needs.

For example the average home uses 25 kWh per day. By consulting a solar radiation map (see next chapter) we find that this house receives 5 daily hours of direct solar radiation averaged out throughout the year.

Calculating the system. Divide the average kWh per day by the average sun hours per day.

25 kWh/ 5 hours = 5 kW system

This 5 kW system will generate 25 kWhs under optimal conditions in *direct* sunlight for 5 hours, or 25 kWh on an average day with some at peak production and most at less optimal angles.

Pertaining to modules

Individual solar modules that are measured in watts have a particular **voltage**, usually around 40 volts and a particular **amperage** (amps), usually around 5 amps. A solar module with 40 volts and 5 amps is called a 200-watt module, which means that it has the potential to produce 200 watts of electricity when in direct sunlight.

In the **Ecopreneur Introductory Training, Module 3: REnU**, you can find a topic called **Estimating the size of your customer's solar system** which contains specifics about the size of REnU panels.

Connecting components

Electrical components, like solar modules or batteries, can be connected in either series or parallel. This makes a big difference in the total quantities produced, as well as their stability.

Each component has a **positive** and a **negative pole** (which you know from trying to figure out how to put 4 batteries into a camera.) The way they are connected makes all the difference.

Series. When you connect things in series, you connect the **+** pole on one component to the **-** pole on the next. When modules are connected in series, the **voltages are added**. Adding voltage is like increasing pressure, the volume stays the same, but the pressure goes up. These modules in series are called **Strings**. The average string is 8-12 modules so the voltage would be 320 – 480.

Since most electrical components are only rated for 600 volts DC, it is rare to see a string larger the 15 modules. On the other hand, since inverters need a minimum voltage or pressure to turn them on, you will seldom have a string size smaller then 6.

Parallel. When you connect components in parallel, you connect **+** poles to **+** poles, and **-** poles to **-** poles. One of the advantages of parallel connection is that electricity continues to flow, even though one of the components (or strings) is damaged. If a system is entirely in series, one damaged component stops the entire system. You may remember old-fashioned series-connected Christmas lights, in which the entire string went out if one light blew (which happened quite often.) Now, the strings are connected in parallel, which you can see because there are two wires connecting each lamp.

When solar modules or strings of solar modules are connected together in Parallel, the **amps are added** but the voltage stays the same. Adding amps is like increasing the volume, the pressure stays the same but the volume goes up. Inverters can only handle so much volume so you will seldom see more than 1-3 strings in parallel.

3 Solar Fundamentals

Quantifying the Power from the Sun

In this chapter you will learn about *units of measure, forms of solar radiation, spectral distribution, energy distribution,* and *solar position.*

Sales Relevancy:

One objection you will hear to solar (solar sales seems to be 70% overcoming objections) is that a site is too cloudy or foggy. To this just ask if they know what countries have the greatest amount of installed solar electricity. The answer is Germany, which lies north of the United States, and Japan, where it is often cloudy, but is where most panels now sold in the US are produced. Because of the way solar modules produce power from direct, diffused and reflected light it works great in these conditions. A very high performing solar array can be found on a foggy beach in Santa Monica.

Measuring Light

Irradiance. The *rate of solar radiation falling on a given area at a moment in time.* Irradiance is measured in units of kW/m^2 (read kilowatts per square meter.)

Irradiation. The amount of solar energy over time. Irradiation is measured in units of kWh/m^2/day and read kilowatt-hours per square meter per day. The map on page 12 shows the average annual solar irradiation throughout the United States.

Deflection. The amount of light lost when the the panels aren't facing the sun squarely as the sun moves across the sky is called deflection. Even though solar cells are etched on the surface into little pyramids to collect light from all angles, coated with a light diffusing coating and protected with light diffusing glass, more light is deflected when the sun is not directly in front of the panels.

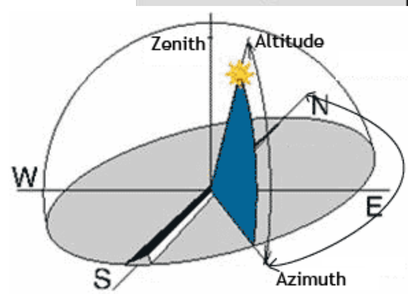
Spectral distribution. the bulk of the solar spectrum which reaches the Earth's surface is ideally suited for conversion by PV cells into electrical energy.

Sun's Position

Two coordinates describe the position of the sun at any given time.

Azimuth. Describes the direction from east to west in degrees (°). North is 0°, East is 90°, South is 180° and West is 270°, as you can see in this diagram of a compass with all of the degrees marked.

Altitude. Measures how high the Sun is from horizon to zenith. also measured in degrees, as shown in the diagram.

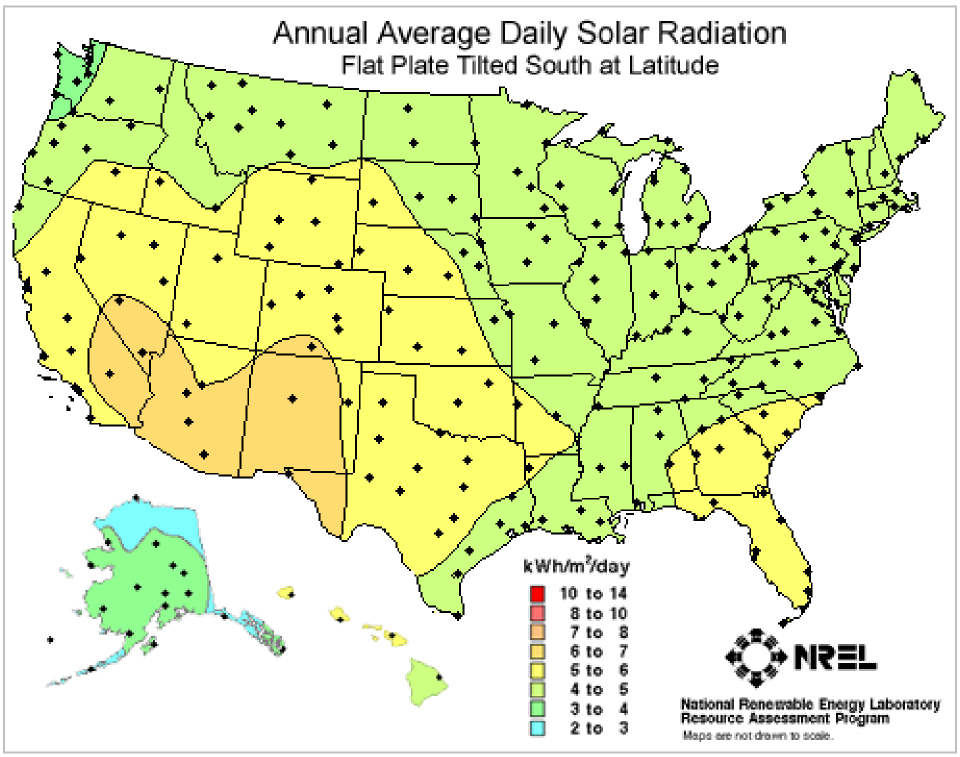


Irradiation example

In the Central Coast area of California (*yellow on the map*) solar systems are sized using an average of 5.5 sun-hours per day. When customers read the models they often comment that their house gets more like 8 to 15 hours of sunlight.

But the sun-hour numbers take into account things like *fog*, *rain*, *night* and, most importantly, *deflection*. The sun-hour rating from the map is the amount of irradiation available to be converted into electricity by a fixed mounted solar array facing true south at the optimal tilt angle. A solar module produces its full rated power only when in direct sunlight, so when the sun is to the East or the West of the module it is not at full production.

Note: *In most of the United States (light green) you can expect 4-5 sun-hours per day, and even in rainy Seattle and most of Alaska, about 3-4 sun-hours per day. This means, of course that more panels are needed to cover consumption.*

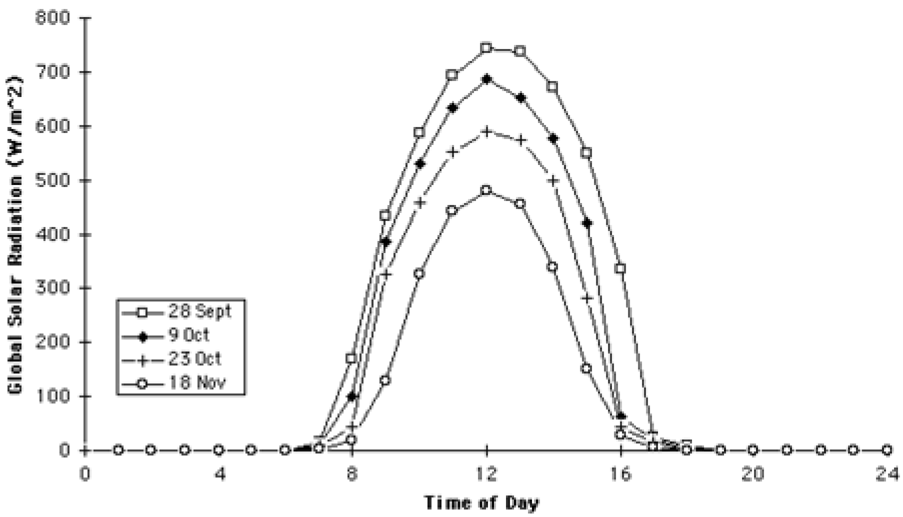


Irradiance throughout the day

The following graph charts a solar module's output facing south throughout 4 days following the fall equinox.

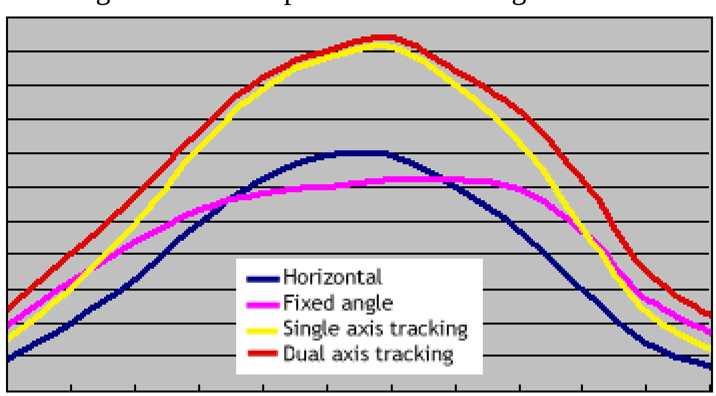
The graph is a bell curve, where peak production occurs around 12 to 1pm with a morning ramp-up and a decline as the sun goes down. This is due to intensity of light as well as deflection.

As the days get shorter, the total irradiation falls as expected. The sun no longer is directly square with the panels, since it is lower in the sky.



Tracking device

The best way to get around this is to put the solar array on a tracking device to keep it in direct sunlight for more time.



The graph shows the *Irradiation kWh/m^2/day* throughout the year on different types of systems:

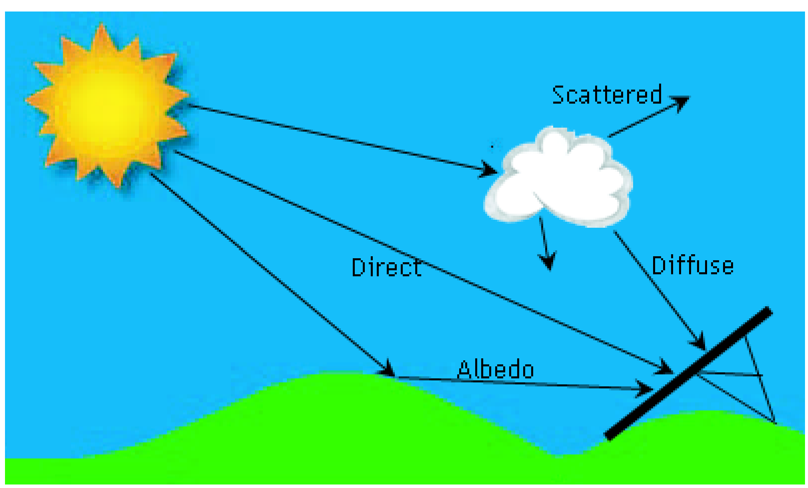
- **Horizontal** or flat mount array favors the summer months when the sun is highest.
- **Fixed angle** at the optimum tilt angle yields the most kWh for a fixed array over the course of the year

Two types of *tracking systems* create dramatically more exposure and higher sun hours all year long, but still more in the summer months.

- **Single axis tracking** tracks from east to west.
- **Dual axis tracking** tracks both from east to west and up and down, following the sun's altitude and azimuth to optimize production throughout the season. In the winter, the sun is much lower in the sky than in the summer.

Forms of irradiance

The sun reaches the panels in various paths, not just directly. Because of that, there may be good generation of electricity on even overcast days. The diagram illustrates these three types of irradiance.



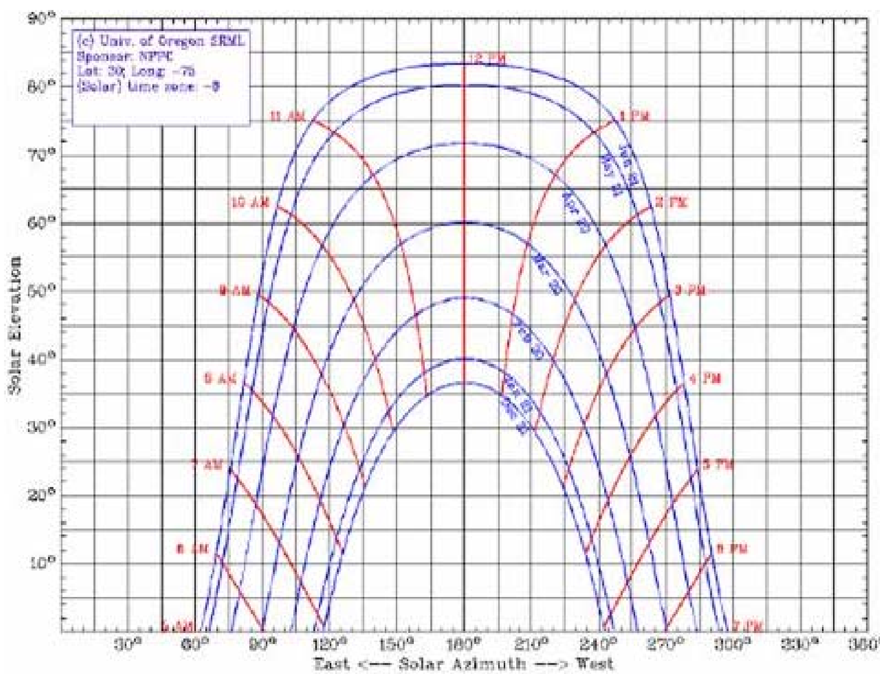
Direct irradiation. A beam of sun light goes straight from the sun to the solar module.

Diffuse irradiation. Scattered light comes from the whole sky. Diffuse is completely absent on a crystal clear day with no clouds or haze and is highly available on cloudy hazy days or in places with lots of smog.

Albedo or reflected light. This is light that is reflected or scattered by the ground or nearby surfaces. Snow gives off a lot of this albedo light and grass or dirt gives off very little.

Sun path diagram

A sun path diagram plots the position of the sun throughout the year. This is very useful when designing and installing solar arrays, to optimize the performance by determining the best angle and to avoid shadows from trees, vents, other buildings, etc.



Solar Cell Physics

In this section we will cover the following topics in a simple theoretical way:

- A little about silicon and the silicon industry
- How a solar cell converts sunlight energy into free electrons: the photoelectric effect.
- How solar cells are doped with specific impurities to create an internal electric field that creates a one-way flow for the free electrons and holes.
- How electrons flow through solar cells connected in series to build up useful voltage.

Note: *For a very articulate and clear explanation of solar cell physics we recommend that you watch the film, **The Science of the Silicon Solar Cell**, available on the UC Santa Barbara site called **The Power of The Sun**, http://powerofthesun.ucsb.edu/. The treatment of the physics in this chapter will be easier to understand after you have watched the video with its graphic presentation.*

Silicon

The material used to make most solar cells today is the element **silicon**. Availability of solar grade silicon has been one of the limiting factors in the solar module manufacturing industry for the past several years.

Sales Relevancy: *You will often hear that there isn't enough silicon to produce all the panels we plan. Citizenre has secured several sources of silicon to ensure our production needs are met.*

The story goes something like this. Solar grade silicon is produced in large scale, expensive-to-build processing facilities. "Well, isn't it just sand?" One might ask. Of course, sand is basically silicon, but with a lot of impurities. **Solar grade silicon** is highly refined silicon that is purified through gasification and then "doped" with precise impurities to create free electrons, which is explained in following sections.

The silicon industry has been hesitant to increase its manufacturing capabilities because they were burned by the dot com crash when extreme growth expectations were not met. The industry made solar panel manufacturers sign long-term contracts at extremely high prices to secure any silicon at all. For example, a solar manufacturing plant, owned by Shell near Los Angeles, slowed production to a trickle because of a lack of silicon. They finally sold to a larger solar manufacture, Solar World, who had secured massive silicon contracts at a better price.

As the industry has matured and showed a steady growth of about 40% a year, the silicon industry is finally responding with new production. At least two new plants are coming on line in Washington State, and there are rumors of several other companies launching new facilities that produce silicon at a fraction of the cost.

At the same time the solar industry has responded with new solar modules that do not use silicon at all. In the following, we look at a silicon-based module, which is what Citizenre is using in the first production facility.

How a solar cell works

Note: *The following explanation is a text version of the graphics you can see in the video* ***The Science of the Sun*** *mentioned at the beginning of this section.*

Silicon crystals

A silicon atom has a positively charged nucleus that is surrounded by negatively charged electrons. The important factor in silicon is that it has 4 outer electrons. These outer electrons are available for bonding to other electrons. Every silicon atom bonds with 4 other silicon atoms to make a repeating crystalline structure.

Monocrystalline silicon. The silicon is grown as large cylinders, which are sliced into wafers that become individual solar cells.

Polycrystalline silicon. Liquid silicon is poured into thin containers and cooled.

Photoelectric effect

The photoelectric effect is a key concept, since it is the way sunlight is converted into free electrons as light interacts with the solar cell.

Note: *Einstein was awarded the Nobel Prize in Physics for his work on the photoelectric effect, not for his work on relativity.*
A lot of the initial practical work was carried out at Bell Labs in New Jersey in the years following WWII.

Think of light not as a wave but as a beam of *photon particles* for this purpose. These bundles of energy penetrate the silicon lattice structure and transfer their energy to an electron in the outer layer. When a single electron gains enough energy from the penetrating photons, it breaks free and floats around the lattice structure, no longer bonded, much like a teenager with a drivers license wandering around and looking for a place to “fit in”.

An electron has a *negative charge*. The silicon atom that loses the electron, which had a neutral charge with the electron, now has a positive charge without it.

Holes

When an electron is removed from the matrix, it creates a *hole* in the outer layer of the lattice where the electron was. A nearby electron with a negative charge soon fills the hole (that has a positive charge.)

As photons penetrate the silicon and knock electrons loose, transferring their energy, negative electrons are forced to move into nearby holes, and positive holes appear where electrons were. For this phenomenon to be functional, a one-way flow of electrons needs to be created to generate electric current.

Doping

Introducing impurities (called *dopants*) into the silicon latticework creates the one-way flow. Two differently doped silicon wafers are layered together to create this flow.

Boron (p-type). Boron has 3 outer electrons, unlike silicon, which has 4. So wherever boron is introduced into the lattice, a hole is created due to the absence of an electron. This hole creates a net positive charge and is filled by a neighboring electron vibrating in to fill the hole there, and leaving a new hole. These positively charged holes move about. Boron doped silicon is also called **p-type,** because the freely moving charge is *positive*.

Phosphorus (n-type). Phosphorus atoms have 5 outer electrons, one more than silicon. Wherever a phosphorus atom is introduced into the lattice, it has a complete set of 4 electrons to share with its 4 silicon neighbors and a 5th electron with no bond to fill. This 5th outer electron breaks free and wanders throughout the lattice. So the introduction of phosphorus provides an electron that moves within the crystal lattice. This type of doped silicon is called **n-type** because the freely moving charge is *negative*.

P/N Junction

The magical flow direction needed to provide current of positive charge in one direction and negative charge in the opposite is created where these two differently doped silicon wafers are "mashed together" as a **diode**. The surface where the where n-type silicon meets p-type silicon is called the **p/n junction**.

Note: *Two oppositely charged materials put together to create an electric field between them is called a* ***diode****.*

At the p/n junction, the extra phosphorus electron breaks free and wanders until it falls into a hole near a boron atom. Since the phosphorus site was electrically neutral before it lost its negative electron, the net charge around it now becomes positive. Similarly, the boron site, which was electrically neutral, now has one more electron, which makes the net charge at the site negative.

This process continues all along the region between n-type and p-type silicon, with extra phosphorus electrons crossing over to fill boron holes. This creates two regions of separated charge, one side positive and the other negative, resulting in a permanent electric field between the silicon wafers at the p/n junction of the diode.

Creating an electric current

The internal field of the diode creates a flow of electric charges *only when sunlight photons strike the silicon*. As the photons hit electrons in silicon bonds, they create hole-electron pairs that are free to separate and wander. Electrons wandering near the p/n junction are pushed in one direction by the internal electric field, while the holes wander in the opposite direction.

This process results in a steady flow of electric charges—an electric current. The flow is *directly proportional to the intensity of light*: **the more photons in, and the more electrons out**.

Cells in Series

Individual solar cells produce only a small amount of voltage, so they are connected together in **series**, *positive to negative*, to produce a useful voltage.

Sales Relevancy: *This illustrates why it is so important for all cells in a module or array to get the same intensity, same direction, of sunlight and not be shaded. The same amount of photons must fall on each cell connected in series to energize the same number of electrons in each successive cell.*

When photons of sunlight strike solar cells in a string, the internal field pushes the electrons out of the cells in a continuous flow through the string. Electrons leave each solar cell with a **net potential gain** of **1/2 V**. The displaced electrons are collected in a **grid** printed on the cells and flow on to the next cells in the string, where they fall into holes.

Module manufacturers connect enough solar cells in series in a single module to produce a useful voltage. The typical high voltage grid tied module has **72 cells in series**. Electrons passing through each cell gain a little more than 1/2 volt so after passing through 72 cells the operational voltage of the module is about **40 volts**. If even more voltage is needed, then modules can be connected in series. For example a typical residential solar array has 8 modules connected in series, resulting in a final operational voltage of about 320 volts.

In summary

You learned about the *Photoelectric Effect,* where photons of light hit electrons in the silicon lattice and provide energy to flow.

Introducing *dopants such as boron and phosphorus* into the silicon lattice provides a direction for the electrons to flow.

Finally, electrons flowing from one cell into the next cell in a module *gain about 1/2 volt* from each cell.

4 *Solar Module Fundamentals & Module Types*

Design Considerations

Solving the shading issue

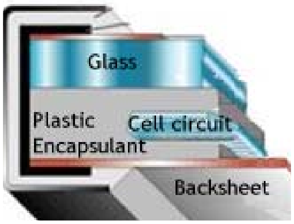
In the previous chapter you learned that a single solar cell created about 1/2 volt so cells are combined in series to add up voltage. Because of this, *shading* could dramatically hinder the flow of electrons through the module and cause a drop in voltage.

Bypass diodes. To protect against voltage drop, bypass diodes are added to strings of cells to allow current from *unshaded* cells to bypass a *shaded* section of cells. Without the bypass diodes, shaded cells would subtract the voltage contribution from the entire module or more.

Consider a module with 72 cells and a voltage of about 40 volts. With three bypass diodes in the module, one for each section of 24 cells, the loss of voltage due to partial shading is limited to only shaded 24-cell strings.

Module Structure

The module structure is designed to protect the solar cells from the environment. It consists of a number of layers to protect the circuit of cells and to make the module easy to install. The materials used in these layers determine the cost and durability of the modules.



- The circuit of cells is encapsulated in plastic.
- A front layer of low iron tempered glass provides high transparency and low absorption and is tempered for strength.
- The multilayered back sheet protects the plastic and cells from abrasions and prevents moisture from getting into the module.
- An edge seal is applied to protect the edges of the glass
- The metal frame is secured around the entire glass laminate. The metal frame gives rigidity and strength to the module and allows the modules to be attached to a mounting system.

Module Designs

Standard Frame Module

There are three basic module designs, the first of which is the standard frame module. This design approach has been used for 30 years and usually involves an aluminum frame that allows the modules to be mounted onto a **rail structure** of some kind. The modules are positioned *above* the roof surface, providing space for air to flow under the module, which helps cool the system and makes it work more efficiently. At the same time, rain water (and roof debris) can also flow under the system.

The rail structure is attached to the roof by means of posts that are secured into the roof rafters with long lag screws. This method is appropriate for most kinds of roofs, including ceramic tile. The roof is sealed tightly after the posts are installed. See the section on racking for more information.

This module design can also be mounted to a **ground based frame** structure. Such a structure can be built on any stable terrain, can be made of metal or wood and can hold the modules at *any tilt angle or azimuth orientation*. The ground mount can even be a *pole structure* to cut down on foundation work and can be stationary or used to *track* the sun throughout the day and year.

Residential roof integrated modules

A second type of module design is one that allows the module to be integrated into residential roofing materials. This is often referred to as a roof integrated module design. The module frame design is modified so that it has the same profile as neighboring flat concrete tiles. The modules are not mounted to a rail structure but are attached directly to the roof surface. This low profile mount allows the module to blend in to the look of the roof and avoid the retrofit appearance of standard mounted modules. The emergence of this more attractive roof integrated product has encouraged many production homebuilders to incorporate solar systems into their projects.

Modified Metal Frame

This type blends in with the roofing materials and is attached directly to the roof surface. There are two types of these modules.

One is the mono crystalline ridged frame design offered, for example, by Open Energy, which is quite efficient and blends well into the roof. It is the same crystalline silicon technology as standard modules but has more frame with fewer cells in series, which can be more expensive. Since it does not have the air flow of standard modules, the cell temperature gets higher, limiting efficiency. (*See the Appendix* page 50.)

The other product, offered, for example, by UNISOLAR, is a *flexible amorphous* technology. It is made to blend in with an asphalt shingle roof. It appears to be somewhat less efficient and to degrade more quickly. The manufacturer claims that this module is better in high shade situations.

Sales Relevancy:

Your customers might request this type of product from Citizenre. We do not currently offer it for three key reasons.

- *It needs to be installed with the roof. Most of our applications will be retrofits. We will seldom have the luxury of installing at the same time as the roof.*
- *Airflow around the modules keeps them cooler, as heat significantly reduces electrical production of solar cells.*

- *The cost per kWh to the consumer is probably greater if the efficiency (power density) is lower.*

Building Integrated PV (BIPV)

The third basic type of module design integrates the module laminate directly as part of the actual building envelope, rather than attached onto the roof or rail structure.

In this approach, the module laminate is custom designed by the architect for a specific building and becomes an architectural element of the building itself. The laminate is usually incorporated into the vertical glass façade of a commercial building. Some BIPV modules do have an opaque back sheet but are made with the cells laminated between two layers of glass, so the module is semi-transparent. A lot of the BIPV technologies are built using what is called thin film technology.

Thin Film Solar

There has been a buzz around thin film for a long time. The southern California solar plant mentioned earlier, just before it went out of business, was dedicating the majority of its growth space to thin film.

It looks like a company named NanoSolar has finally worked out some of the technological barriers to thin film and is launching what they promote as the new wave of solar modules—the technology that will allow every home and business to have solar arrays.

The NanoSolar technology is not made out of silicon like most modules. Here is the company's description of what they have done:

Note: *The liquid in the flask in the picture is the solar "ink" used to print the film.*

"The "absorber" (semiconductor) is the most critical layer of a solar cell. Nanosolar has developed techniques by which a thin film of Copper-Indium-Gallium-Diselenide (CIGS) can simply be printed (solution-coated) to create an efficient solar cell with unprecedented yield, materials utilization, and throughput.

Conventionally, CIGS thin-film solar cells have been fabricated with vacuum deposition techniques such as sputtering or evaporation. While such vacuum techniques work well for producing small CIGS cells in a laboratory, the process cost of these techniques is so high that the result is not an inexpensive cell relative to the per-square-meter economics that the solar industry requires.

Printing is by far the simplest and most robust technique for depositing thin films. But, of course, this would require a CIGS ink to print, and such a break through ink, composed of nano particles of CIGS material, would require solving an entire array of fundamental science challenges. But this is just the fundamental advance that the NanoSolar team has managed to deliver."

Time will tell if thin film or some other technology will be the next big thing. For now, silicon-based ridged-frame modules are the most proven method of converting sunlight into electricity and has the best power density to cost ratio. There is another more power dense and economical technology that is being used on a utility scale and has been rumored for residential applications for the past few years and that is solar concentrators.

Solar Concentrators

There are several types of Solar Concentrators.

The first use mirrors on trackers to concentrate sunlight in one location to boil water to turn a turbine. This is the same way coal plants work, utilizing the concentrated energy of the coal to heat water and turn a turbine.

The second method of solar concentrators, and the one most likely to make it to a consumer level, utilizes a silicon cell just as described above. In the concentrator module the cells are housed in a deep mirror box that only works when the *sun is directly above* the box. For this reason all of the modules need to be on *dual axis trackers*. The mirrors capture more sunlight and concentrate that light onto the panels, so far fewer cells are needed to create the same amount of power.

The picture shows a home application of concentrators installed in 1998. As you can see, the module is much thicker than a normal module and the array is mounted on a dual axis tracker. Most applications are utility scale and a single module will produce about 30kW, and are much bigger than this.

5 The Complete Solar Array System

Overview of Complete System

Note: *This is based on information currently available about Citizenre's unique system components.* ***It will be updated as more information becomes available.***

In this section we examine the major components of a typical grid connected system to demonstrate how all the parts work together. Then we look at how energy flows through different systems through the course of normal operation.

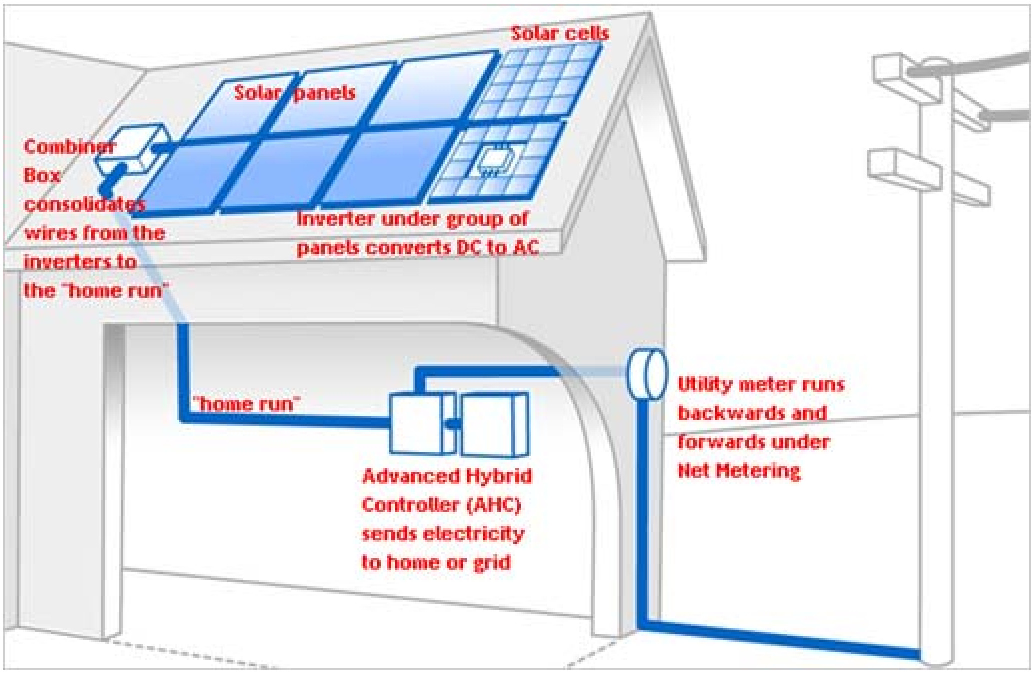
This diagram of a complete solar system was adapted from the graphic available on the *jointhesolution.com* website. It shows in a schematic way all the major parts of the system that will be installed on residential roofs.

The **solar pv modules (panels)** consist of **solar cells**.

Under a small group of panels will be installed an **inverter** to convert the DC current directly to AC. This is a particular innovation with the Citizenre system, to prevent loss through transmission.

The small box to the left on the roof is a **combiner box**, which collects all the wires from the stacking series strings into parallel runs to reduce the amount of wire coming off of the roof.

The next element is called the **home run,** whcih usually runs the wires in a conduit attached to the outside of the house, or through the attic or inside the wall. In the case of a ground mount, this conduit may also be run under ground to the house.



The home run ends in the **Advanced Hybrid Controller (AHC)**, which determines if the current should be used in the house, or sent to the grid.

Note: *Some states require **dual (2) meters**, where one shows energy fed to the grid and the other, energy drawn from the grid.*

From here the power runs through the **house** running any loads like refrigerators, computers, air conditioners or lights.

The excess power that the house loads are not using flows to the grid via the **meter**, which is running backwards.

Using the power throughout the day

Morning. The solar power generated in the modules travels from the array through the AHC directly into the house circuits. At the same time power from the grid is pulled into the service panel to supplement the solar power

Noon. The solar power flows to the AHC which determines how much is needed for the house loads. Excess power flows through the utility meter onto the grid, spinning the meter backwards and building a credit with the utility company. These credits get used when the solar array is not covering all of the load needs, such as at night and on rainy days.

Night. All of the house loads are fed by the grid power. This is when our customers use the credits they built up during the day.

Power Outage. The inverters have what is called an "anti-island" device. This will not allow the system to function without grid power. So when the grid goes down it also shuts down the solar array. This is to avoid shocking a repair person working on the lines. However, in time, Citizenre will be including a manual switch that will allow the customer with a 25-year contract to power their home with solar during an outage.

Mounting systems on the roof

Solar mounting is secured to the roof rafters (for tile roofs, after first removing tiles) at regular intervals with a stainless steel lag bolt holding in a *solar jack foot* or *L bracket*. Each point of jack ranges from about 2 to 6 inches above the finished roof.

All penetrations are flashed and sealed and fully warranted by the installer for typically 10 years, according to state laws, which vary from state to state.

After the solar jacks are installed, rails may be laid across them and secured to each post. Typically all of these components are aluminum or stainless steel.

Then the solar modules are mounted to the rails with clamps, usually two per side, or in some systems, directly to the jacks.

The underside of the solar modules floats above the roof about 3-8 inches so air can flow through and cool down the array.

The entire structure weighs only about 3 pounds per square foot when installed. This is very light and usually does not call for any engineering of reinforcements to the roof, which is usually required at about 10 pounds per square foot.

Inverter fundamentals

Changing DC to AC with maximum results

Note: *At festivals and events where solar power is used, the musicians, who are accustomed to running on a diesel generator are always very impressed by the lack of humming in the equipment.*

The inverters transform the Direct Current (DC) power from a group of solar modules into Alternating Current (AC) power to match the grid and be useful for most house loads.

The inverter is a power conditioner that creates pure sine wave power (AC.) This power is cleaner in most cases than the grid because it is conditioned right on site.

Maximum Power Point Tracking (MPPT). More than just creating clean AC power, inverters also maximize the power output of the solar array in a function known as Maximum Power Point Tracking (MPPT). As you learned in the module section, solar modules produce the power at the voltage they are connected to. The maximum power point voltage changes as the sun moves throughout the day and the current (amps) gets higher and lower. This allows the inverter to produce the most amount of power at any given time without frying its circuitry.

Inverter failure. Inverters are the one component that needs to be replaced periodically. Most systems installed today use a single inverter for the entire system, so when it fails, the whole system stops providing electricity to the home.

Citizenre is working on innovations for our inverters to deal with this challenge. One of the great aspects of our solar solution is that with our "performance guarantee" any inverter issues will not be a concern for the customer.

Note: *The following information will be updated soon with information about the actual REnU system.*

REnU inverters

Citizenre is planning on using its own inverters, possibly with an inverter for each panel or small group of panels. This has several advantages:

- If an inverter fails, only one panel of the system will be affected, which will be reported in our daily monitoring.
- This allows for better scalability, in that we do not need to have different inverter capacities for different system sizes.
- The efficiency of the system is improved, since DC loses more energy than AC going through a wire.

6 Rate Schedules

Sales Relevancy: *Although Citizenre's rate is flat, knowing rate structures provides you with the very convincing sales argument—that we are cheaper!*

Usually, the electricity rate structure is the highest factor in determining the customer's payback or cash flow.

Citizenre's rate is simple and fixed—the average published rate from the previous year, and it is not going to go up or change in any way for the entire length of the contract. This is a simple flat rate.

Flat Rates

Some utilities also charge a simple flat rate, for example, this bill from Los Angeles Department of Water and Power.

Los Angeles Department of Water and Power

P.O.Box 30808 Los Angeles CA 90030-0808 Web site at http://www.ladwp.com

PAGE 1

11083 BATON ROUGE AV

Bill Issued 11/06/06 **Due Date 11/30/06**

Amount Of Previous Bill $ 536.61

Payments Since 09/07/06 $ 536.61-

DWP ENERGY SERVICES- 1(800)342-5397

This Bill Covers 09/05/06 To 11/03/06.

Energy Used 2358 KWH*

GreenLA Program 14.16

Meter 02-Electric Total $ 260.77

$ 4.42 is your daily average cost for energy.

Note: *Remember some utilities charge for water and/or gas on the same bill.*

In this example, the rate can be calculated by dividing the price of electricity, $260.77, by the energy used, 2358 kWh. The rate for electricity, on this bill, is $0.11059 per kWh.

Sales Relevancy: *The other key thing to note about LADWP is that it has the dirtiest power in the entire state, mainly from coal. It's been exempt from California's clean air standards until a recent lawsuit. The outcome of this lawsuit is that LADWP now needs to conform to the state law, which is mandating 20% clean energy for all utilities by the year 2020.*

Citizenre's price for power in the LADWP area, $0.103 per kWh, is slightly less, so Citizenre's bill for this same amount of power will be $242.87, a $17.90 savings for this month. This family will be able run their home on clean renewable energy for less than they are paying for dirty grid power.

When the rate is lower than Citizenre's. It is worth noting that LADWP also has other, l**ower rates** than Citizenre is currently offering. When a customer pays at these rates, we remind them that although Citizenre's price maybe slightly higher the first year, it will never go up for the entire length of the contract. Within a year or two, the utility's rate will exceed our rate as raw materials and commodity pricing continue to increase.

LADWP has already voted to increase rates for the first time in many years and is now negotiating how much. By registering now, customers will lock in the extraordinarily low rate. A year after the rates increase, the Citizenre rate for new accounts will also increase.

This flat rate from LADWP is one of the lowest in California. The reason it is so low, when the rest of the state and houses right across the street in a bordering utility are paying considerably more for power, is **deregulation**.

LADWP is what is called a *municipally held utility*, run and governed by the city council and is not driven to make a profit. In some cases it is subsidized. Most of the investor-owned utilities have a different rate structure, called a tiered rate.

Sales Relevancy:

Track your customers' utilities, both how they charge and where their energy comes from. Use the Internet to find your state's public utilities commission and search for posted utility tariffs.

Many states also require the utilities to post their annual air quality emissions -- these are great things to know when talking with customers.

It can also be interesting to look for the top polluters in your zip codes. You will most likely find a power production facility on that list.

Tiered Rate

In a tiered rate structure, power consumers are charged according to the amount of electricity they consume in blocks of rates. The first block or tier is called baseline. This is usually the minimal amount of power needed to run a refrigerator and a few lights and is relatively inexpensive. The tiers are rated in percentages above baseline, as in this example from Pacific Gas and Electricity.

ELECTRIC ACCOUNT DETAIL

Service ID# : 1357913579
Rate Schedule: E1 TB Residential Service
Billing Days: 30 days

Serial	Rotating Outage Blk	Meter #	Prior Meter Read	Current Meter Read	Difference	Meter Constant	Usage
Z	10	63L788	61,553	62,553	1,000	1	1,000Kwh

Charges

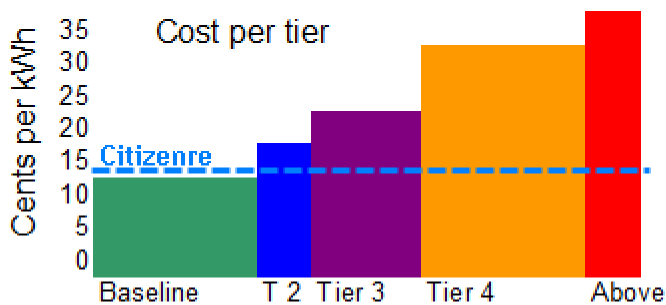
03/15/2006 – 04/14/2006

Electric Charges			$208.40
Baseline Quantity	306.00000 Kwh		
Baseline Usage	306.00000 Kwh	@ $0.11430	
101-130% of Baseline	91.80000 Kwh	@ $0.12989	
131-200% of Baseline	214.20000 Kwh	@ $0.21314	
201-300% of Baseline	306.00000 Kwh	@ $0.29007	
Over 300% of Baseline	82.00000 Kwh	@ $0.33039	
Net Charges			$208.40

In the example, the baseline quantity is 306 kWh and is billed at $0.11430 per kWh. As the customer consumes more electricity, the price increases to $0.12989 for the next 91.8 kWh, $0.21312 for the next 214.2 kWh, $0.29007 for the next 306 kWh, while any power consumed above this will be in the 5^{th} tier and billed at $0.33039 per kWh.

Note: *Assuming they have roof or ground space in the sun for about 600 ft^2 solar modules...*

If this customer had Citizenre panels, he would pay rent based on the average published rate for PG&E for the year before he signed on, $0.128 per kWh, which is slightly higher then baseline but less than half of the 5^{th} tier. The two rate examples are shown graphically in the figure on the next page.



This means that for almost all customers, owners of condominiums, town homes as well as large homeowners, the total rental fee averages toward baseline. For most of our customers in a tiered pricing structure, the prices are going to be about half of what they are paying now, and will not follow the skyrocketing projections for the future.

Note: The average utility increase from 1970-2000 was 6.7%. After deregulation rates have been increasing much faster for most utilities.

In the example the customer is paying $208.40 for the same amount of energy that Citizenre would charge $128 in rental fees. This is over $80 savings each month with no upfront investment. Now if we take this out over time with a mild 5% growth rate on the utility price for energy, this customer would save tens of thousands of dollars over a 25-year contract switching to Citizenre while running on clean renewable energy.

Sales Relevancy:

If the customer asks, "How is that possible? This sounds too good to be true!" just reply, "We do not need to raise our rates every *year, because our fuel source, sunlight, is free. It is not going up in prices, we do not need to pay for generation or distribution, we do not need to fix or repair long power lines or invade foreign countries to secure it. The utilities have to pay market value for a finite commodity that is becoming scarcer with each passing day. This is just a better business model. It is not that it is too good to be true, it is just that it's been so bad for so long."*

And the deal gets possibly better with a Time Of Use rate structure.

Time Of Use (T.O.U.) rates

Some utilities offer a Time Of Use billing. A T.O.U. meter registers usage *according to the time of day the energy is drawn from the grid*.

Since it is more expensive for utilities to provide power at certain times of the day, they have established these rates to encourage conservation when it is needed most.

Season	Time-of-Use Period	Energy Charge[1/, 2/] ($/kWh)					"Average" Total Rate[3/] (per kWh)
		Tier 1 (Baseline)[4/]	Tier 2 (101-130% of baseline)	Tier 3 (131-200% of baseline)	Tier 4 (201-300% of baseline)	Tier 5 (Over 300% of baseline)	
Summer	Peak	$0.20861	$0.22420	$0.32417	$0.41658	$0.46501	$0.15922
	Part-Peak	$0.11178	$0.12737	$0.22734	$0.31975	$0.36818	
	Off-Peak	$0.09422	$0.10981	$0.20978	$0.30219	$0.35062	
Winter	Part-Peak	$0.12417	$0.13976	$0.23973	$0.33214	$0.38057	
	Off-Peak	$0.10046	$0.11605	$0.21602	$0.30843	$0.35686	

This T.O.U. bill example has a tiered structure as well. It is split into five different periods, each with its own tiered rate (*see previous section on tiered rates*.) The summer months, defined as May through October, have three periods: **Peak** 1 pm-7 pm, **Partial Peak** 10 am-1 pm and **Off-Peak** 7 pm-10 am. Winter is structured similarly, in this case with lower rates, since this utility has a higher demand in the summer and electricity is more expensive when demand is high.

Save with T.O.U.

In areas where T.O.U is available, some of our customers may be able to save considerably by switching to a T.O.U. meter. This will depend on the average rates overall. The engineer will be able to advise the customer about this possibility.

Sales Relevancy: *It is important to find out how electricity is consumed at each site and then educate customers on how to change usage patterns or rate structures to maximize their benefit of the solar array. The engineer will also work this out with them during the site visit.*

For example, if a home owner is gone all day and can concentrate most of the major loads such as pool pumps and laundry to off-peak times between 7 pm to 10 am, they can back-feed most of their solar power to the grid at peak or partial peak times, creating credits at a very high rate ($0.20+) that they can use at a very low rate ($0.09) at night.

In this scenario the customer only needs to produce about half the kWh they use to zero out their bill, particularly with west-facing arrays. South and east may work too, depending on the load times. On the other hand, if they have an east-facing array with heavy afternoon loads, this rate structure will be even more expensive.

Reserve capacity

By law, each utility must have a certain percentage of reserve capacity above peak (*the most power that is ever used at any one time*) in production *potential* at all times.

Note: *Grid energy is not stored, but monitored.*

The utility starts off the day with a few generators running. These will be "baseline" plants, which may be operated using coal, diesel, nuclear or natural gas.

As demand rises throughout the day, generation capacity needs to increase. For a while, the utility can simple increase output of the generators, by “turning up the throttle.” When each is running at full capacity, the utility needs to engage a whole new generator or power plant to keep the required percentage above-peak demand in reserve potential, or standby.

Requirements for peak load are increasing constantly, because of growth in demand in our modern society. The utility has to keep increasing its potential for production, or the amount of energy it has in reserve from wholesale producers, *which it may have to pay for in advance in some districts*.

One reason utilities tolerate and appreciate net metering is because it can shave the utilities' peak load by supplying the grid when the utility needs it most.

EV Rate

In some utilities there is a T.O.U meter available for electric car owners. This is an amazing rate structure that is extremely high in the day and very low at night. When you hook even a small PV system into one of these, the owner is basically driving for free.

Note: *If you are thinking about getting a new car consider going electric when you have panels to generate their power. They are fast, silent and clean, with virtually no maintenance and a very long life. Most of the original electric vehicles were leased, and then taken away and discontinued. (See the movie, "**Who Killed the Electric Car?")***

There is one remaining in the used market—the Toyota RAV4 and a few more are about to be released—the Tesla for $100,000 and Phoenix for about $20,000. Zap Motorcars is about to release a few models as well. There are also small electric vehicles to use around town, called tNEV or Neighborhood Electric Vehicles, which are great for most driving needs, even though they only go 25 mph. When you can charge it on your solar array, you have virtually free transportation!

***Plug-in Hybrids** are becoming more available, combining the savings of solar-generated electricity with the convenience of gas. See http://www.evworld.com/electrichybrid.cfm.*

7 Site Assessments

Is the Site Eligible?

Now that you have a basic understanding of solar fundamentals and the factors involved with solar electricity production, you can apply this knowledge to an actual physical location and learn the variables associated with each of your clients' sites.

It is best to sign up only customers who have a high likelihood of installation. This section covers those factors.

Sales Relevancy:

Eligibility is not a given in the Citizenre program. Just because a customer has a high bill does not mean Citizenre will automatically install a system at their site. The engineer may find that there is no reasonable place to put the system or the customer will not want the system in the only sunny spot.

The internal projections are that only 50% of the customers who sign up will actually get installed. It is great to watch your numbers rise and to move quickly through the comp plan, but not if the systems are not going to be installed. You get paid for installed systems.

There are three major factors to consider when evaluating a site. The first two are on the FRA:**solar exposure** (Ridgeline Orientation and Shading Factor) and **electricity usage** (Average Monthly Bill). The third and equally important variable is the amount of **available space**.

Solar Exposure

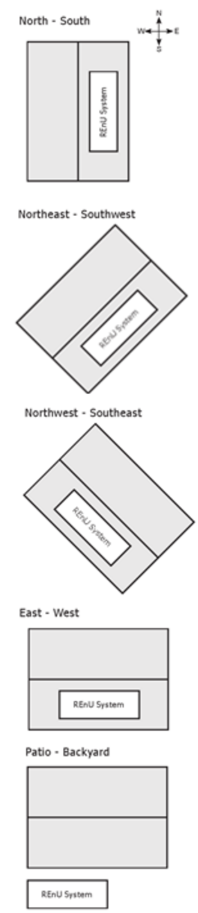
Solar exposure has two parts, the orientation of the panels, and how much shade will fall on the panels during the day, from trees, other buildings or even a hill.

Orientation

The direction the panels will be exposed can be ascertained by determining the ridgeline orientation.

Sales Relevancy:
Many customers are confused by this question at first. Take the time to explain it and find the right answer. They may not be accustomed to thinking in directions such as East and West. Simplify the question to terms that are familiar, such as "Where does the sun rise at your house?" By the description they give about the sunrise and its relationship to the house, you will be able to figure out the ridgeline orientation. (You know, of course, that the sun rises in the East!)

The ridgeline is where the major roof slopes come together. For example a house with an East-facing slope and a West-facing slope would have a North-South ridgeline. When meeting customers face to face it may be helpful to have a picture to demonstrate this. The illustrations here can be downloaded as a PDF by clicking the **?** next to Ridgeline Orientation when you sign up a customer.

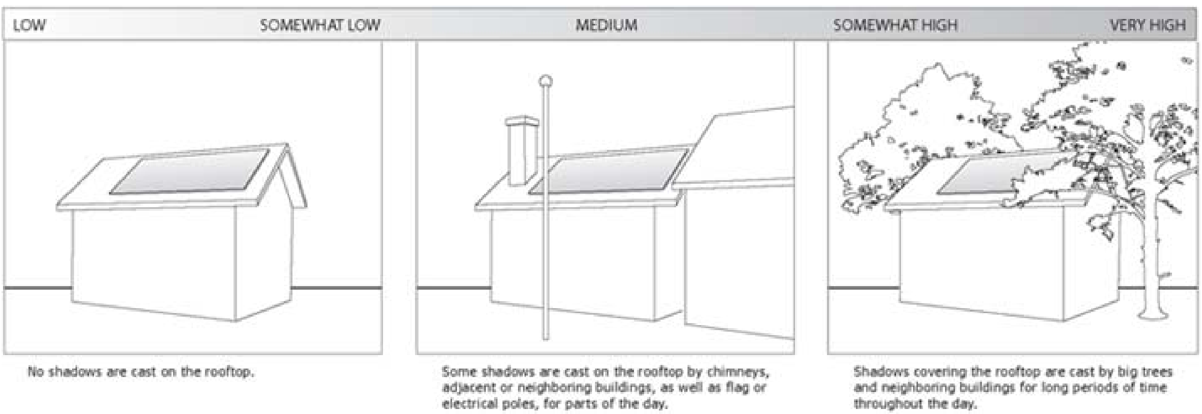


At the ideal orientation, the solar array will produce the maximum amount of kWhs per year, since the solar panels will be in direct solar exposure for the most time.

In the Northern Hemisphere, the ideal orientation for a solar array is **South, 180°**, while the **tilt angle** should be approximately **latitude - 15°**. For example, since the latitude in Southern California is about 30°, the optimum angle for the solar array there is 15°.

The appropriate orientation is usually between SE (120°) to SW (240) and a tilt angle of 0° (flat roof) to 45° (12:12 Pitch). In some locations, such as Austin, Texas, and California, utility rebates are structured best for West-facing roofs to aid the utility in peak power shaving when they need it the most.

Shade The second part of solar exposure is shading factors. Shading is a crucial component. If the panels are facing south at the perfect angle but are shaded for a majority of the peak hours the system will produce very little power. The ideal in this case is **no shade**. A tolerance of morning and evening shade is most likely acceptable with at least full sun from 10 AM to 3PM. This illustration can also be downloaded when you sign up a customer of the New House page.



The ideal system is a **ground mount dual access tracker with no shade.** This has the fewest solar panels, and generates the most electricity in a given area. However, Citizenre does not include trackers in the initial offerings

Electricity Usage

The total electricity usage for a year for the site is also of great importance to determine elegibility. Usage can be estimated by asking the dollar amount of the bill.

- Typically for bills that are at most $40 per month averaged over a year, the economics do not work out. The bill is so low that there is very little incentive for either the customer or Citizenre to install a very small system.

- For monthly bills ranging from $50 to $90 it starts to make sense for both parties, although the customer may not see a savings for a few years. Their new rental bill from Citizenre will be about the same as their old utility bill until the unavoidable electricity rate hikes bring the utility rate higher then the Citizenre fixed rate.
- The magical number seems to be around $100 per month. A customer with a $100 bill or higher will most likely see a cost savings the very first month with Citizenre and that savings will only grow over time as utility rates increase.
- For a very high bill, it is less likely a solar system from Citizenre will offset all of it, since the maximum size is 10 kW. But the balance of the two bills, the reduced electricity bill and the new solar rental bill, will be lower than the old bill.

12-month history

The engineer will look at at least 12 months of electricity usage history and ask as many questions as possible to determine future electricity usage. This is a crucial issue because net-metering credits expire after 12 months.

If we oversize a system, the customer pays Citizenre for all their generated power while building more credit with the utility company than their annual consumption. Since the credit at the end of the twelve-month cycle disappears, they will be paying Citizenre for power generated but not used.

Typically at the end of the 12-month cycle the customer owes the utility for a small amount of usage, since the day or summer time credits were not quite enough to cover the night or winter charges.

Utility billing

Each customer will receive an invoice every month with typically around a $5 meter charge, which will be due, as well as a record of credits or charges so they can decide each month if they want to carry a debit in hopes it will be off set by a future credit, or pay the amount then so it does not build up too much.

Sales Relevancy:

Work at filling in all the information on the FRA as accurately as possible. At the same time gather as much site and electrical usage information as you can. You can record this data in the Comments section of the Customer Account page.

Weed out any customers that are blatantly not going to work. You will not have false hopes about future compensation, you will not have to repay the 10% IRA, and Citizenre's resources will not be wasted chasing down poor prospects.

Citizenre will be evaluating each Ecopreneur on the number of FRAs that are actually installed, so your own assessment of a customer will improve your rating as well.

Other helpful information

Meter location

How far is the meter from the best location to install the solar array?

- If the solar panels are being installed on the same building as the meter, they may be less than 100 feet from the meter.
- If the panels are to be installed on a separate building, such as a detached garage, barn or guest house, there may be trenching involved.
- In the case of a ground mount, how far away is the location from the meter or nearest sub panel?

Rate schedule

You learned in the previous chapter on rate that how a customer pays for their utility electricity will influence how much benefit they get from a solar array.

Sales Relevancy:
Familiarize yourself with the different rates offered by your local utilities so you will know how to interpret your customer's rates.

Find out what rate the potential customer is currently paying.

- Some homeowners are on level pay. This means they pay the same amount every month regardless of how much energy they consume. On the 12th month they either owe money or the utility owes them.
- Some customers are on a disability type of subsidized rate that is much lower than standard rates. In such as case a $50 bill will represent much more power consumption then a standard $50.
- Some customers get a monthly discount for allowing the utility to shut off their air conditioning, hot water heater or other large electrical use during peak draw times when needed.
- Some customers have multiple accounts—one for the house, one for a well, another for a shop or small commercial use.

Find out as much as you can. People love to talk about their homes and their lives and you can learn a lot about not only their situation but also how utilities operate in your area. Remember to record this information in the Comments section.

Time Of Use metering?

This is also an opportunity to see if your customer's lifestyle would benefit from **Time Of Use (T.O.U.)** metering (if it is available from their utility.) If the residents are gone most of the day and they are willing to concentrate their loads in the evenings, such as pool pumps, laundry, etc. , they fit the profile for T.O.U. For them, solar may be an even better deal since we can cut the actual size of the system to cover their needs by 20% due to the higher credits from day-time generation and lower night-time rates for usage.

Future changes

While asking your customers about their current rate, you may also find out about future energy changes such as *additions* in the case of "We are going to add a pool," or *decreases* such as, "We are putting in new energy efficient windows and appliances."

If a customer knows in advance that two of their children are about to leave for college in a few months, they may want to start with a much smaller system. On the other hand, if they know an elderly relative may be moving in with them soon, they may want to oversize the system.

Available space

A crucial factor is having enough space in the sun with the proper orientation.

Note: *A more precise calculation for the Citizenre panels is described in the REnU module of the Introductory Training.*

The *average* home needs about a 5 kW system to offset their annual usage. To calculate the physical size of this system, you can use this simple rule of thumb:

$$10\ W\ /\ ft^2 \text{ of space}$$

A 5 kW system covers about 500 ft^2 of roof or ground area.

$$5000\ W\ /\ 10\ W/ft^2 = 500\ ft^2$$

Sales Relevancy: *A good site evaluation will help weed out customers who are not eligible for our program and maximize the benefits for those who do get a REnU System with Citizenre.*

You may never see any of your customers' homes but you can find out a lot by asking simple questions.

Most 2,000+ ft^2 homes have 500 ft^2 in the sun somewhere, since the 500 ft^2 does not need to be contiguous. The system can be placed in different sections, for instance, 250 ft^2 each on the garage and the house.

The minimum system that Citizenre is offering is 2 kW or 200 ft^2. The systems cost money to make, install, maintain and administer. If a system is smaller then 2 kW there is very little value to the customer and the operating expenses would be too high for Citizenre. The maximum system size for residential customers at this time is 10 kW or 1000 ft^2, because of net-metering limitations.

Always ask each customer if their home has 200 - 1000 ft^2 in the sun, depending on the size of their bill.

- If they say yes, there is a high likelihood we can make it work if the other factors are acceptible.
- If they are doubtful, tell them that we may not be able to help them.

Take the Test!

Now take the ***Solar Competency Test*** and help more customers!

Appendix

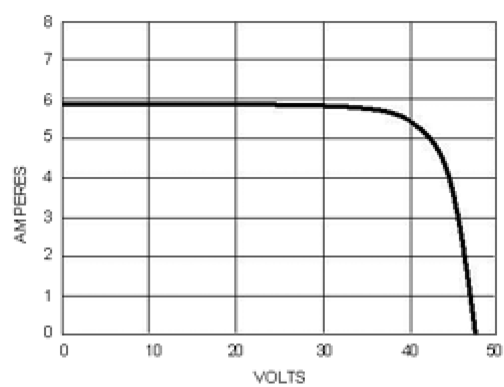
Current-Voltage Curves, Testing & Rating

Note: *The information in the appendix is for the more technically minded. You will probably never encounter a need to know this when you are talking with customers. Nevertheless, you might be curious to know some of the science behind the engineer's assessment.*

Standard Current-Voltage (IV) Curve

The IV Curve is perhaps the most important technical aspect of a solar module and it forms the basis for understanding all PV array design. It represents the *possible values of output current (**I**) and voltage (**V**)* that a solar module can deliver under specific environmental conditions.

The model demonstrated in the graph can output at **voltages** ranging from zero to about 48 volts. You can read the specific **current** associated with every voltage from the graph.



Reading the IV Curve

If the module is outputting to a 12-volt battery, you can determine the watts output to the battery from the graph. Read up from 12 *volts* to the IV curve and then over to the Amperes scale to find that the *current* output would be about 5.9 amps. Since *power (in watts) equals voltage times current*, this means that the module would be outputting into the battery at a rate of about 71 *watts*.

Output value

This particular module is rated for a *maximum* output value of 215 watts (where the curve turns,) but the *actual* output of the module depends entirely on what it is connected to.

A solar module is a "passive" device. This means that it does not dictate its operating voltage, which is determined by whatever it is connected to. If it is connected to a battery, the *battery voltage sets the voltage point* for the module.

If we can operate the module at 40 volts, the IV curve shows that the module output current is about 5.4 amps, corresponding to the maximum rated output power of 215 W. Compare with outputting to a 12-volt battery, the current level does not drop very much while the voltage increases greatly, with much higher output power.

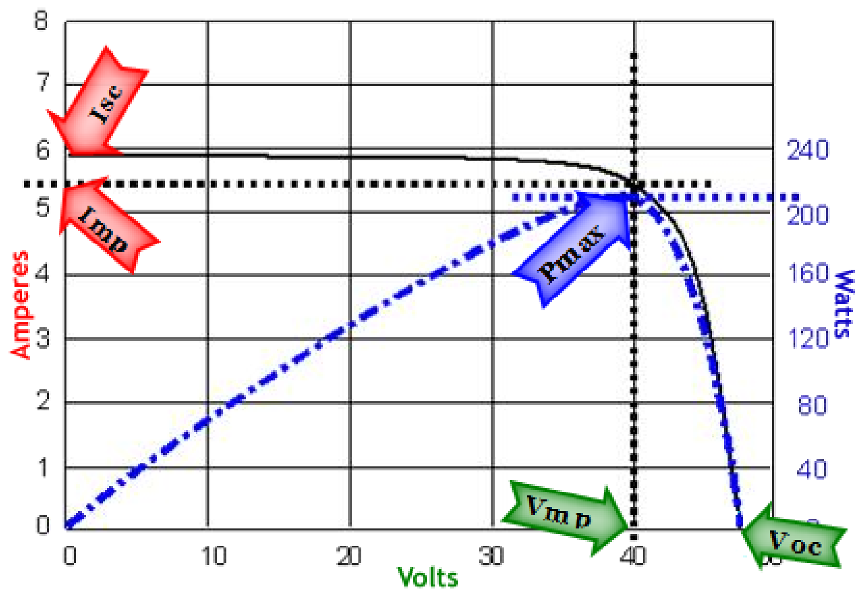
However, if we operate the module at yet higher voltage, like 45 volts, we see that the corresponding current drops drastically to about 3.5 amps, dropping the corresponding output power to about 157 watts. As you can see, the *peak output power from a module occurs right at the knee of the curve.*

Key values

There are five key values that can be read from a module IV curve. All manufacturers of solar modules list these five values on all their module spec sheets.

Power Voltage curve (P-V)

The IV curve graph shows the current at various voltages. The blue curve is a **power voltage (P-V)** curve measured in *watts*. This shows how the output power at first increases from zero, then peaks at 215 watts, and then falls off back to zero.



Note: *Remember that **I** stands for current in amperes.*

Short circuit current (Isc). The first key value to read from the curve is the **short circuit current** or **Isc** in this case 5.8 amps. There is *zero power and voltage* at this condition. It corresponds to the positive and negative lead from the module being connected together, making a dead short. This is not dangerous, as it would be for a battery or generator. The module is inherently safe in this regard. The current output is limited by the amount of sunlight coming in.

Open circuit voltage (Voc). The second key value is the open circuit voltage or **Voc**, in this case 48.3 volts. There is *zero power and current* at this point. This corresponds to the two leads from the module being unconnected to anything. The circuit is open so there is no place for the current to flow. An analogy would be water behind a dam. There is maximum pressure, or voltage, but no flow of water, no current from the module.

In between these two extreme points of zero power, the module can produce various power levels depending on the voltage.

Voltage at Maximum Power (Vmp). The *voltage* that corresponds to *Maximum Power* is called the Voltage at Maximum Power or **Vmp**, in this case 39.8 volts.

Current at Maximum Power (Imp). This corresponds to a *current* at *Maximum Power* or **Imp**, of 5.4 amps.

Maximum Power (Pmax). The *product* of these two values is 215 watts, the *Maximum Power* or **Pmax**.

Environmental conditions

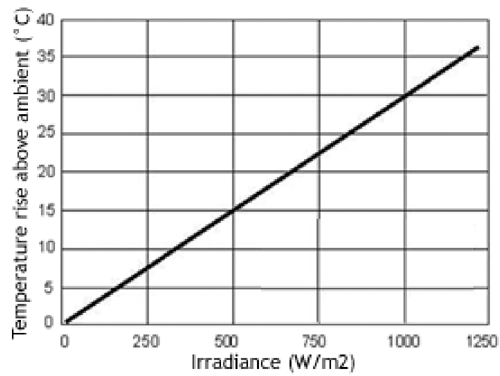
The IV curve on the next page has values based on given environmental conditions. If those conditions change, the output potential of the solar module and the IV curve that represent that potential change.

Temperature

Cell temperature. Cell temperature in a module is not the same as the outside (ambient) air temperature. A module in the sun heats up above the ambient temperature *as a linear function of the irradiance* (for a standard rail mount.)

Note: *These rates are always indicated as ° C. The conversion is: ° C x 1.8 + 32 = ° F*

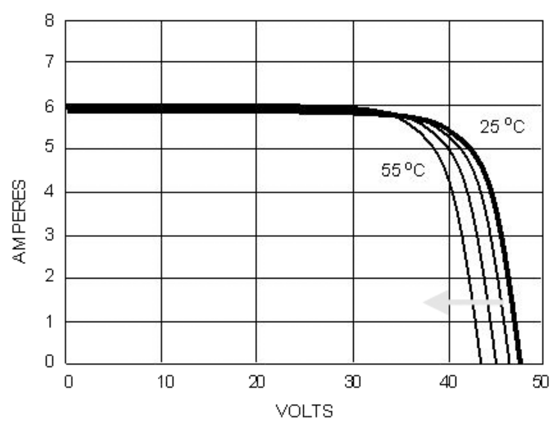
In the example shown, if a module is getting 500 W/m2 solar irradiance, the cell temperature will be 15° C above ambient.
If the ambient at that time is 40° C (104° F), the cell temperature in the module will be 55° C (131° F).



Similarly, 1000 W/m^2 solar irradiance at 40° C (104° F) ambient means a cell temperature of 70° C (158° F)

Output related to temperature. Voltage potential is *inversely* proportional to cell temperature. As the cell temperature goes up with increased irradiance, the *voltage potential of the module goes down*. The IV curve basically shifts backwards. The short circuit current goes up a little, but this effect is very small compared to the loss of voltage potential.

The **Temperature Coefficient of Voltage** gives the amount of voltage change *inversely* with temperature. For the example module it is -0.137 V / ° C change. It is very important to realize that voltage goes *down* as the temperature goes *up* and vice versa.



Temperature Coefficient of Voltage = -0.137 V / ° C
Temperature Coefficient of Power = -0.38% / ° C

The overall *power* output of the module also drops with rising temperature. The amount is given by the **Temperature Coefficient of Power** of -0.38% per ° C rise.

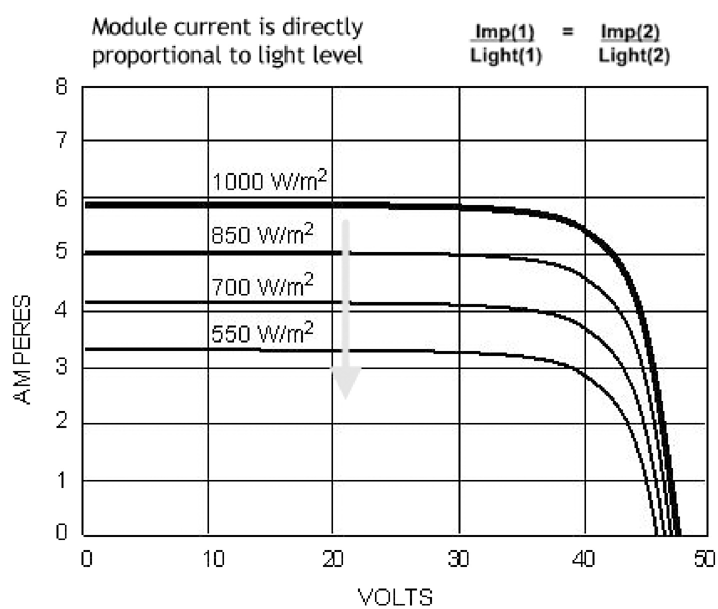
Sales Relevancy: *As irradiance and cell temperature rise during the day, voltage and power go down, while there may be more power produced in a cool climate.*

Example. Let's look at an example case of how the module max voltage and power would change when heated. If a module heats up to 55° C on a roof, then difference to standard temperature of 25° C is 55° – 25° = 30° C.

- Multiply this change in temperature times the **Temperature Coefficient of Voltage** to find that the Vmp would drop by 4.1 volts. Subtract the voltage change from the standard Vmp value of 39.8 to get a new Vmp of 35.7 volts.
- Using the **Temperature Coefficient of Power**, the loss of power would be 11.4%, resulting in an actual power loss on the hot roof of 190.5 watts.

Light

The IV curve is *directly proportional* to the amount of **light** hitting the module. The graph shows the IV curve at different light levels.



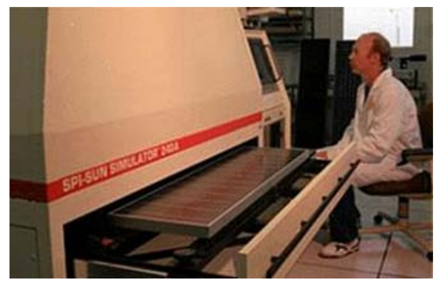
Testing and Rating Solar Modules

Standard Test Conditions (STC)

Because module outputs are so dependent on the environmental factors of **irradiance level** and **cell temperature**, standard test conditions (STC) have been established and accepted by all solar manufactures worldwide. These standard test conditions are

- **25 ° C cell temperature**
- **1000 W/m2 solar irradiance**

These conditions are replicated by solar manufactures when testing production output in their solar simulators, like the one shown here.



Power ratings

You may have noticed that many solar module manufactures have different power ratings of from 10-50 watts for panels that look the same and are the same exact size. For example, an Ever Green 140 module is the same size as 150 and 160 modules.

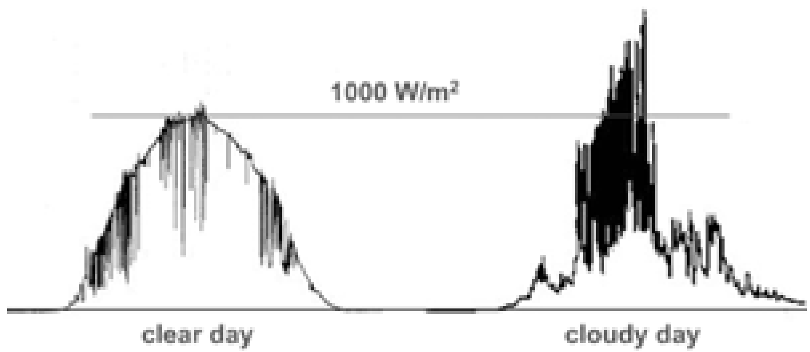
This is because in the production of solar cells, some cells are capable of producing higher or lower amounts of power. All the cells are sorted during manufacturing into three classifications: A cells, which produce the highest, B cells, and C cells.

It is crucial that a solar module be comprised of all the same kind of cell or the power output will be compromised. So the Evergreen 160 module is all of the A cells and the 140 is all the C cells.

Exceeding standard peak irradiance

The standard peak irradiance level of 1000 W/m^2 is not an absolute maximum, and it can be exceeded under a variety of conditions.

Shown here are actual traces of solar irradiance over a clear day and a cloudy day. The peak on the clear day was 1000 W/m^2.



The afternoon light levels of the cloudy day are quite low due to the cloud cover, but in the morning as the clouds formed, there were times when the total irradiance was actually much higher than 1000 W/m^2.

Edge of cloud effect. The high morning levels occurred because light reflected off the sides of the white billowy clouds and acted like other sources of light, producing a sum total that was greater than just what the sun would normally produce. This is often called **edge of cloud effect** and can result in irradiance levels of 25% or more higher then the standard peak of 1000. This is why the National Electric Code (NEC) specifies that conductors and other current protection devices that carry solar-generated current be oversized by a factor of 25%.

PTC

Another set of test conditions has been defined to set more realistic values than measured at STC. These are called **PTC**, which stands for **PUSA Test Conditions**, where **PUSA** stands for **Photovoltaic for Utility Scale Application**.

This is a national cooperative research project begun in 1986 that involved a consortium of utilities doing real outdoor testing of modules and inverters. One of the results of that field-testing was a method of determining module output that involved more realistic conditions than STC.

The **irradiance** level is still set to 1000 W/m^2. With the **ambient temperature** at 20° C and allowing a small **wind** of 1 m/s (about 2 mph) the module is *allowed to heat up* to whatever temperature it does, usually about 26° C above the ambient of 20° C.

The maximum power output under those conditions is the PTC rating of the module. This slightly more realistic power value is used by the CEC, California Energy Commission, for their rebate calculation, and is being adopted by other states and utilities for their programs as well.

CEC

CEC uses an even lower value than PTC—the AC output of a solar array. Using the PTC rating of the array, it multiplies the total DC output with the **inverter efficiency,** typically about 92%-95.5%.

Sales Relevancy:

STC, PTC, CEC. All of these different values mean extremely different things and can lead to a lot of confusion for both customers and sellers.

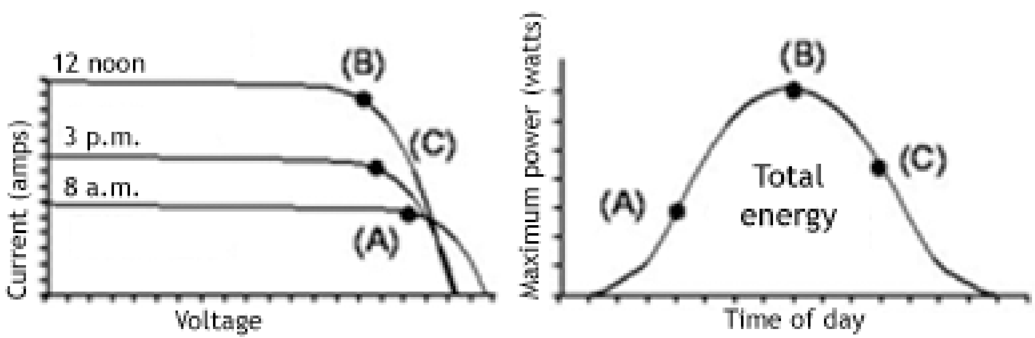
If the customer is considering systems from companies representing their systems using a different values, it is very difficult to make a comparison. The customer will be confused if two companies are selling the same product with the same price but use different ratings. One salesman might claim the system is a 5 kW system and will cost $8 per watt using the STC rating. The other is more interested in giving the most conservative payback and energy production figures, so he is selling a 4.4 kW system at $9 per watt CEC. Both are selling the same system at the same price, but the customer thinks he'll get a larger system at a lower price if he goes with the PTC vendor.

The same issue arises for a ***sales person*** *when negotiating commissions, which are usually on a per watt basis: STC or PTC?* ***Prices*** *might be set on STC and* ***rebates*** *on CEC, depending on the state.*

One of the great things about Citizenre is that all of these issues are mute. The customer simply pays for the electricity they produce and we handle all the rest. Simple.

In summary

All this data on IV curves and how the environment affects them can be compared using a series of IV curves over a typical day and plotting the associated max power over time.



Looking at the module IV curves on the left is like looking at individual frames of a motion picture. Each represents a snap shot of the potential production at a given point in time. The curve on the right shows the output over the entire day.

In the *morning*, curve A shows that the current output level is low while the voltage potential is high. The light level is low because that sun is at a bad angle to a south facing roof and the cell temperature is low because the module has not heated up yet.

By *noon*, curve B shows that the current level has raised to its peak but the voltage point has moved in a bit. The sun has moved to face more directly on the module, while the module has heated up.

Then in the *afternoon*, curve C shows that the current is dropping back down, while the voltage is beginning to move out again. The light level is dropping as the sun moves toward sunset and the module is cooling off.

Sales Relevancy:

Modules are tested under extreme conditions to ensure their production values over time under adverse conditions. Tell your customers that the modules can withstand golf ball-sized hail at terminal velocity (as fast as they can go) and that the first modules ever made are still producing power. Almost all silicon crystal based modules are warranted to produce at least 80% of rated value for 25 years.

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