Walking Down the PV Shopping Aisle

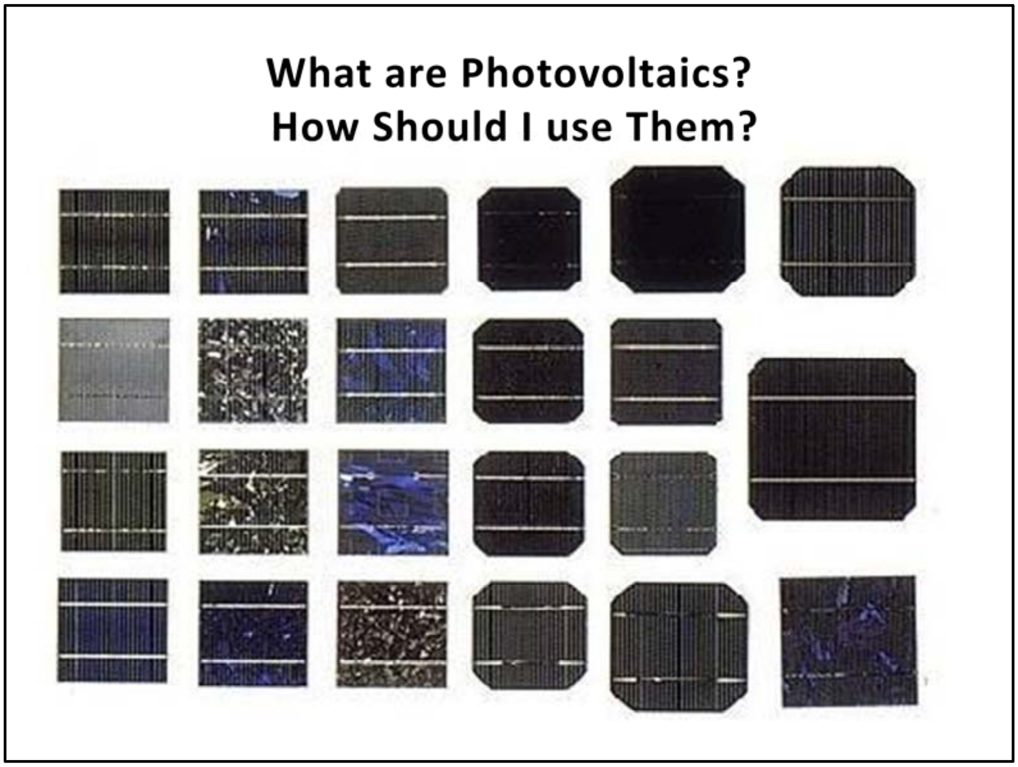
A PV system should fill your needs.

You should look at using a PV system if it fills your needs or, does it operate better and cost less than other alternatives that are available to you. The cost of the photovoltaic material is dropping as more factories are built, and the demand is increasing as it becomes economically more viable to install solar power. However, kilowatt-hour for kilowatt-hour, the cost of PV energy is still generally higher than energy bought from your local utility. Keep in mind the initial cost of PV equipment is higher than other types of energy producers but there are many applications where a PV system is the most cost-effective long-term option. The number of installed PV systems is increasing this year because the government Tax Credits and utility rebates have brought the long term cost and payback time down to closer match the other power sources .

There are several issues to consider when planning a PV site:

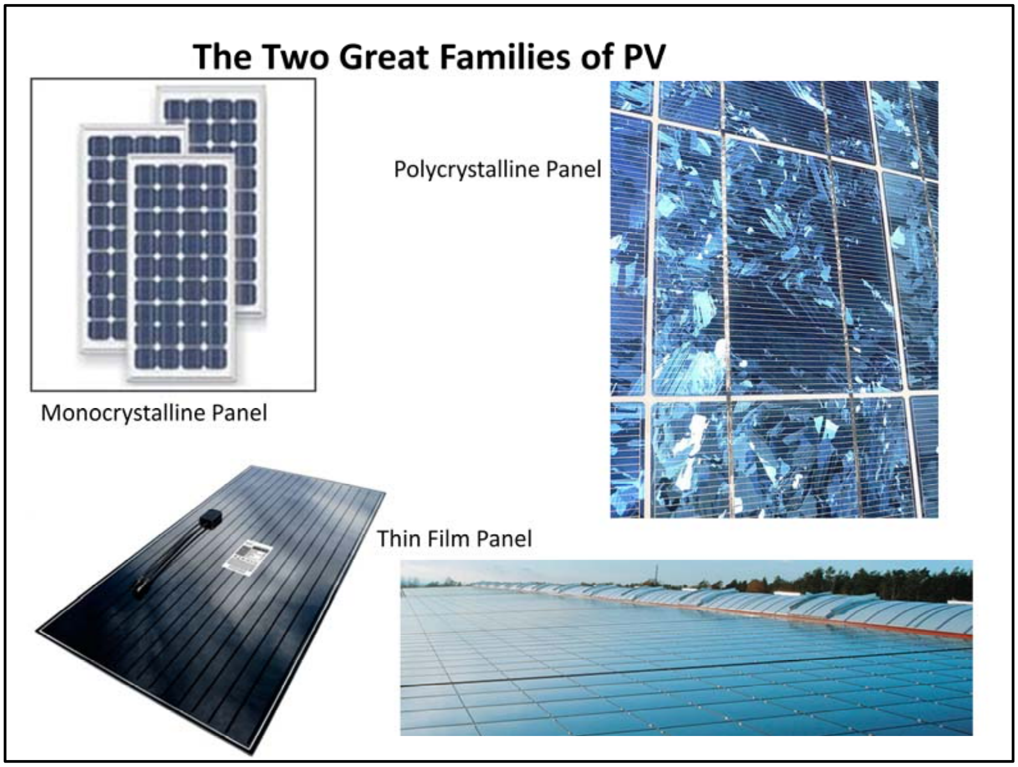
First is the Site Access - A well-designed PV system will operate unattended; it will require some type of remote security and will require some periodic maintenance.   A PV system can be designed for easy expansion. If the power demand increases in future years, the ease and cost of increasing the power supply should be considered and if possible designed for.   What is the local Environment - PV generation systems create no pollution and generate no waste products in their production of electricity. However high salt content in soils, floods and brush fires can all create unexpected and expensive maintenance costs. Look down the road most PV modules available today are based on proven technology that has shown little degradation over the past 15 years of operation. Finally, cost, for many applications, the advantages of PV systems offset their relatively high initial cost.

System designers like POWER know that every decision made during the design of a PV system affects the power delivery, maintenance, lifespan and so the cost. If the system is oversized because the design was based on unrealistic requirements, the initial cost is increased unnecessarily. When less durable parts are specified, maintenance and replacement costs are increased. The overall system life-cycle cost (LCC) estimates can more than double if inappropriate choices are made during system design. Don't let unrealistic specifications or poor assumptions create unreasonable cost estimates and keep you from using this attractive power source. As you design your PV system, be realistic, flexible and open to new technologies.



Photovoltaic (PV) technology allows for the direct conversion of sunlight to electricity using semiconductor devices called solar cells. Photovoltaic's are almost maintenance-free, some have no moving parts, and the PV material as a whole seems to have a long life span. The photoelectric conversion process produces no pollution and can make use of free solar energy. Overall, the longevity, simplicity, and minimal resources used to produce electricity via PV systems make this a highly sustainable technology.

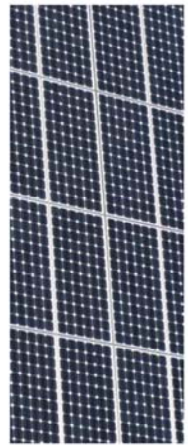
The typical photovoltaic module that most of you have seen is actually made up of many PV Cells. A single PV cell is a thin semiconductor sandwich with two layers of highly purified silicon. The layers are slightly doped – one layer with boron and one layer with phosphorous. Doping produces either a surplus or deficit of electrons depending on the side of the cell. When sunlight hits this sandwich, a voltage difference between each side of the wafer develops. In silicon, this voltage difference is about half a volt. Metallic contacts are made up to each side of the wafer; an external circuit is added and if the sun hits it, current flows. Since the output of one cell is not substantially useful, we assemble a number of these PV cells in series and parallel combinations to create a PV module.



A PV module is encapsulated in tempered glass (or some other transparent material) on the front surface and with a protective weatherproofing material on the back. The edges are sealed, and there is often an aluminum frame holding everything together to form one mountable unit. A junction box and/or wire leads are typically found on the back of the unit to allow multiple modules to be wired together. The positive and negative DC lead can then be tied in series to increase the voltage to match the particular inverters requirements.

Here is how the performance shakes out for these two kinds of PV:

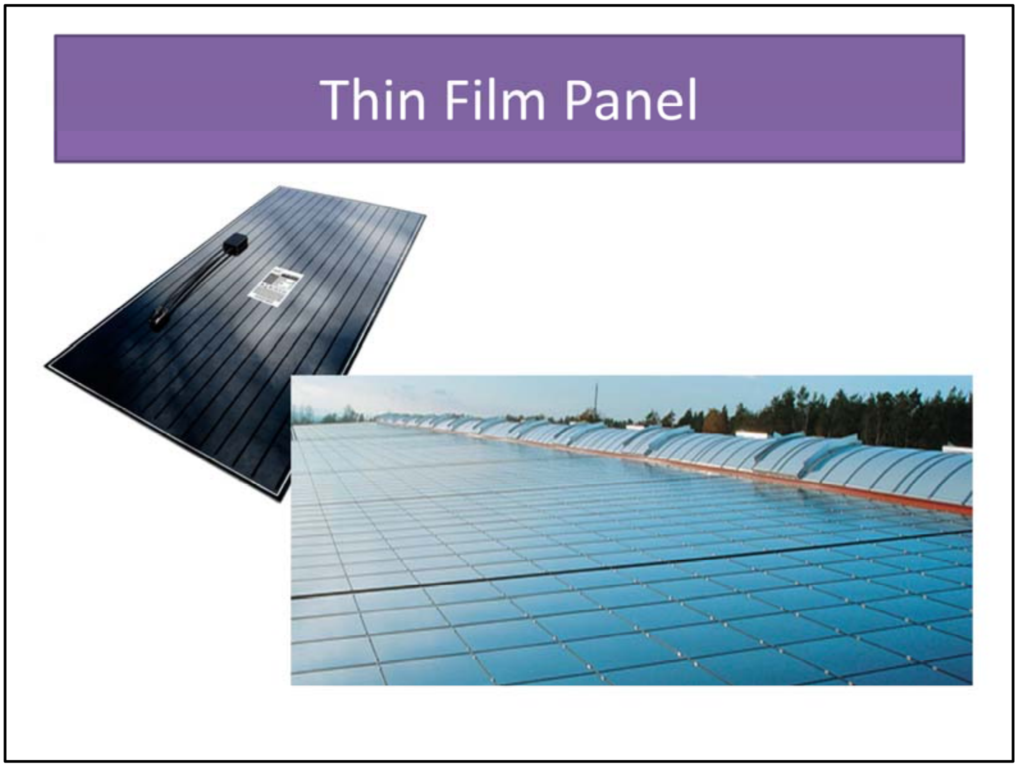
Monocrystalline Panel



Monocrystalline Cell Types: Typically, dark blue or black in color, these represent the oldest PV device type and are typically most expensive to produce. This type of PV cell material is usually the most efficient at converting sunlight to DC. Current modules' sunlight-to-wire output efficiency averages 10% to 12%, with a few achieving efficiencies as high as 19%. Performance degradation rates are typically slow with this module, averaging 0.25% to 0.5% of capacity per year, with vendor guarantees on power production of 90% for 10 years, and 80% for 25 years. Output efficiency of crystalline PV modules decrease by 0.5 per cent per degree Celcius over the standard test temperature of 25°C. Good ventilation is required at the back of modules. Exposure to cool breezes when mounting modules is an important consideration and will increase output.

Polycrystalline Panel

Polycrystalline Cell Type: These cells are also blue in color but appear fractured or crystalline. Due to the different manufacturing process, these modules tend to be less expensive than the single crystalline cell and are slightly less efficient averaging 9% to 11%. Degradation rates and vendor guarantees for this type of module are similar to those for the single crystalline cell.



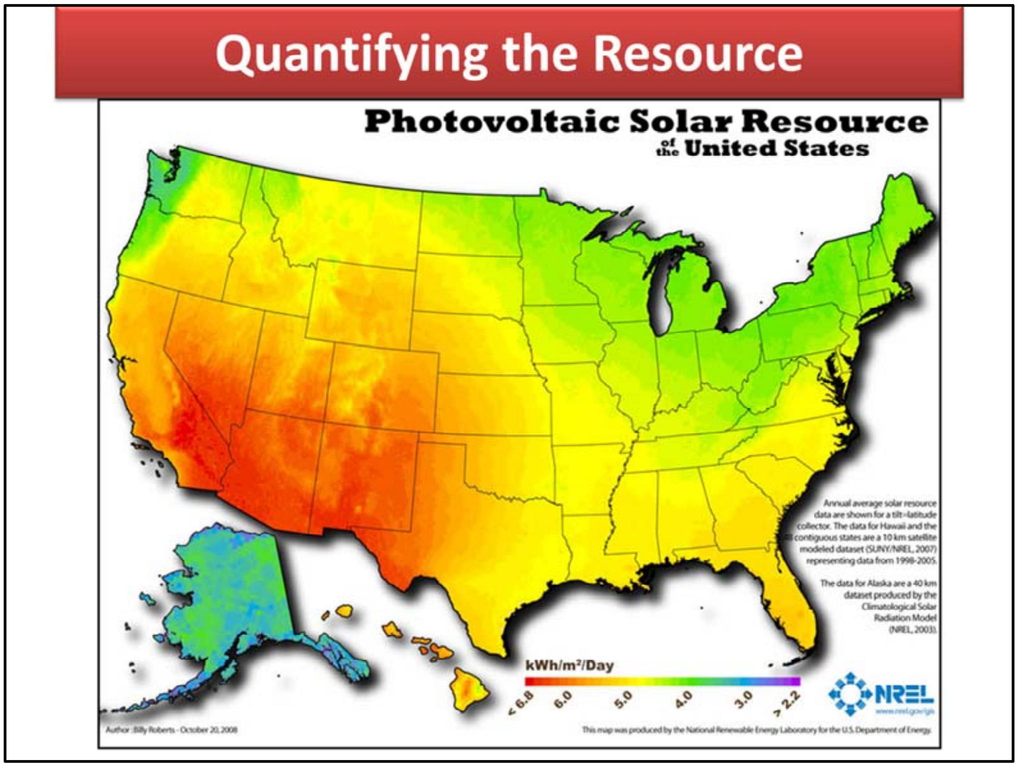
Amorphous or Thin Film Type: (a-Si)**:** Typically black in color, these cells are produced by a technique in which the silicon material is vaporized and deposited onto glass or stainless steel. Because a-Si absorbs light more efficiently than its crystalline counterpart, the a-Si solar cell thickness can be 100 times less, thereby significantly reducing materials cost making this by far the least costly production technology. Companies like uni-solar are utilizing a flexible, stainless steel substrate and polymer-based encapsulates, PV products utilizing that technology can be very lightweight, flexible and durable. This can provide a savings on shipping, transport to remote rural areas, and installation breakage. The tradeoff to the lower cost is the lower efficiency of the cell itself thin film cells deliver a PV module that is less efficient than single crystalline cells at turning sunlight into electricity, averaging 6% to 9% in conversion efficiency. Degradation is similar to that seen in the technologies noted above. Unlike in other module types, when glass is used for these modules it is usually not tempered. The high temperature silicon deposition process can result in embrittlement of the glass, so site breakage may be a problem with some thin film modules and should be addressed in any construction scope of work. There are many new companies coming to the market with amorphous cells having different light absorption properties that are deposited continuously, one on top of another during fabrication enabling the PV to capture a broad solar spectrum of light more effectively. This increases the energy conversion efficiency of the multi-cell device and improves performance stability. The multi-junction approach has resulted in world record efficiencies for these cells.

PV Basics

PV CELL OVERVIEW			
SINGLE CRYSTALLINE	**POLYCRYSTALLINE CELL**	**STRING RIBBON**	**AMORPHOUS OR THIN FILM**
Typically dark blue in color	Typically dark blue in color	Typically dark blue in color	Typically black in color
Efficiency averages 10% to 12%	Efficiency averages 9% to 11%	Efficiency averages 10% to 11%	Efficiency averages 6% to 9%
Degradation averaging 0.25% to 0.5% per year	Degradation averaging 0.25% to 0.5% per year	Degradation averaging 0.25% to 0.5% per year	Degradation averaging 0.25% to 0.5% per year
Vendors typically guarantee power 90% for 10 years , 80% for 25 years	Vendors typically guarantee power 90% for 10 years, 80% for 25 years	Vendors typically guarantee power 90% for 10 years , 80% for 25 years	Vendors typically guarantee power 90% for 10 years, 80% for 25 years

Model using NREL (SAM) Solar Advisor Model

PV Efficiency: On average, the sun delivers 1,000 watts (1 kW) per square meter at noon on a clear day at sea level. This is defined as “Full Sun” or irradiance, and is the benchmark by which modules are rated and compared. This is not a value that can be achieved in practice, since dust, water vapor, air pollution, seasonal variations as well as altitude and temperature all combine to reduce how much sunlight the modules receive. Keep in mind also that the conversion process itself is subject to chemical and thermodynamic limitations. So PV modules do not convert 100% of the energy is sees into electricity. Current technology averages 10% to 12% conversion efficiency. The energy production for an active solar system depends upon the amount of available solar radiation, projected uses of the system, and the proper system design. It’s useful to look at the standard measurements for quantifying what the owner can get out of the system however location and maintenance will affect the output.



Solar irradiance:

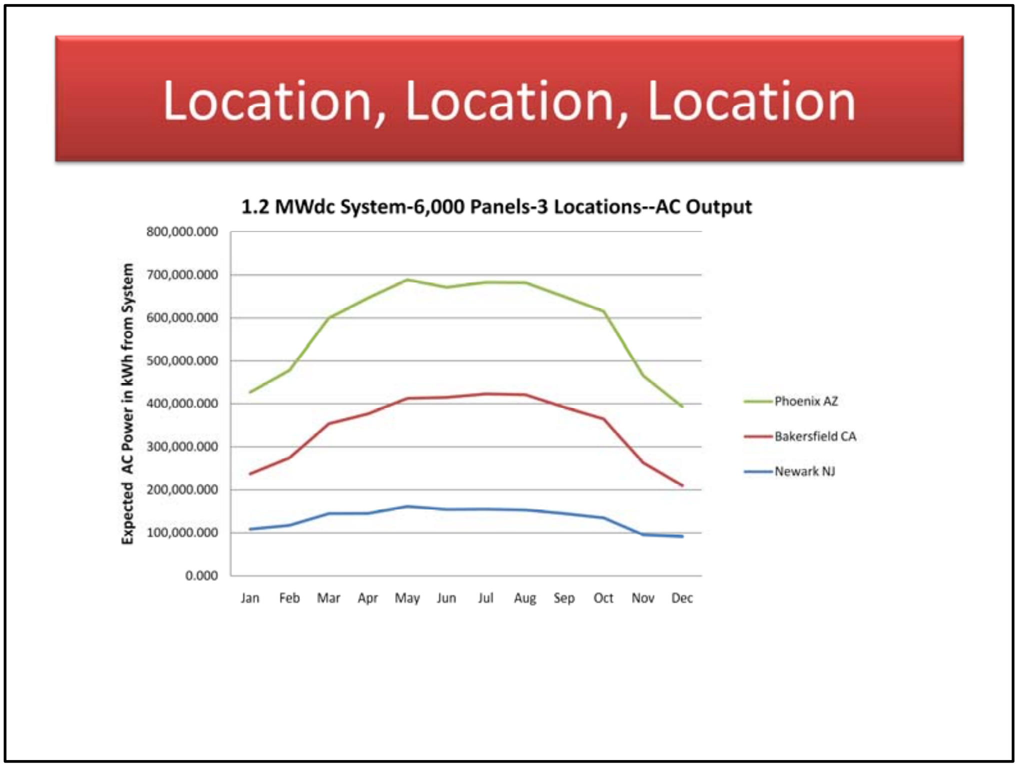
All life on earth is supported by the sun, which produces a large amount of energy. Only a very small percentage of this energy strikes the earth but that is still enough to provide all our needs. Solar radiation strikes the earth's outer atmosphere at a "Solar Constant" of 1.36 kilowatts per square meter. Approximately 70% of the suns radiation makes it through our atmosphere on a clear day in the southwestern United States.

Solar irradiance or the density of radiation that is incident on a given surface at ground level regularly exceeds1,000 w/m2 and in some mountain areas, readings over 1,200 w/m2 are often recorded.

Average values are lower for most other areas, but maximum instantaneous values as high as 1,500 w/m2 can be received on days when puffy-clouds are present to focus the sunshine. These high levels seldom last more than a few minutes because the atmosphere is such a powerful absorber and reduces the solar power reaching the earth at certain wavelengths. The maximum irradiance is available at solar noon, defined as the midpoint, in time, between sunrise and sunset.

The part of the spectrum used by silicon PV modules is from 0.3 to 0.6 micrometers, approximately the same wavelengths to which the human eye is sensitive. These wavelengths encompass the highest energy region of the solar spectrum.

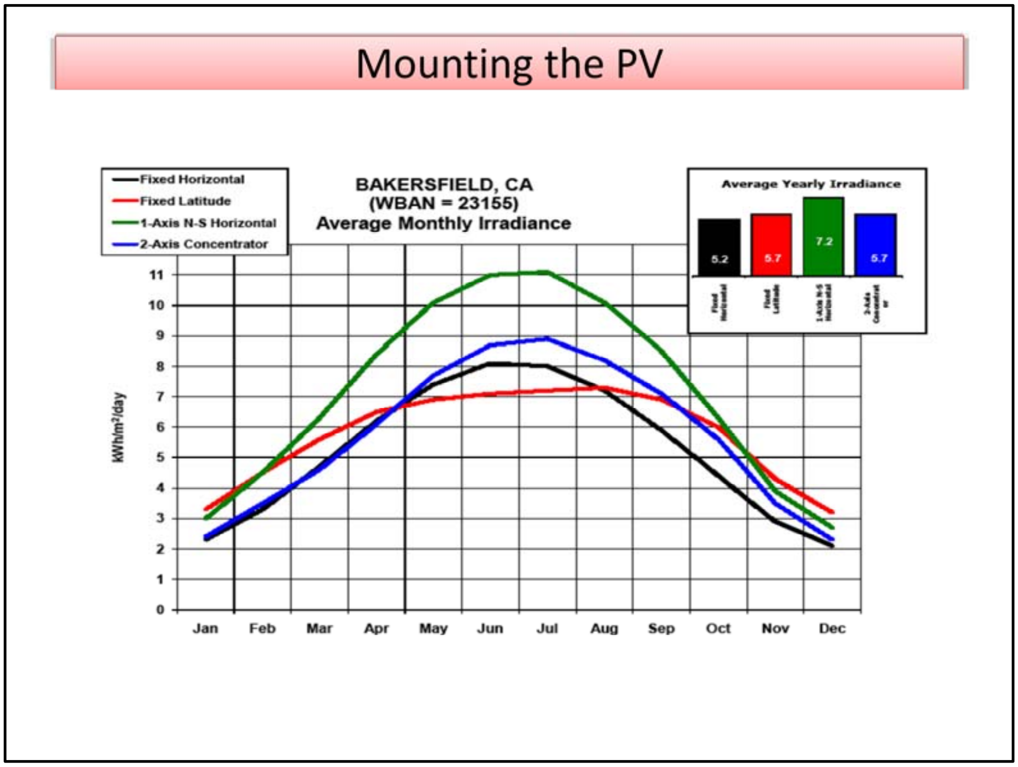
Talking about solar data requires some knowledge of terms because the solar radiation varies between the short days of winter to the long days of summer. On any given day, the amount of power that will actually hit your solar panels will fluctuate continuously from sunup to sundown depending on cloud cover, sun position, or how dirty the air may be.



Solar Insolation: Sun hours per day
Solar insolation differs from irradiance because of the inclusion of time. Insolation is the amount of solar energy received on a given area over time measured in kilowatt-hours per square meter (kwh/m2) this value is equivalent to "peak sun hours". Peak sun hours is defined as the equivalent number of hours per day, with solar irradiance equaling 1,000 w/m2, that gives the same energy received from sunrise to sundown. Peak sun hours correspond directly to average daily insolation given in kwh/m2. Many tables of solar data are often presented as an average daily value of peak sun hours (kwh/m2) for each day, month or year.
Insolation varies seasonally because of the changing relationship of the earth to the sun. This change, both daily and annually is the reason some systems use tracking arrays to keep the PV pointed at the sun. For any location on earth the sun's elevation will change about 47° from winter solstice to summer solstice. For any location the sun angle, at solar noon, will change 47° from winter to summer.

Using inaccurate solar data will cause design errors, so you should try to find accurate, long-term solar data for your system location. This data is becoming more available, even for tilted and tracking surfaces. Check local sources such as solar system designers, installers, universities, airports, or government agencies to see if they are collecting such data or know where you might obtain these values.

A photovoltaic array can be mounted at a fixed angle from the horizontal or on a sun-tracking mechanism. The preferred azimuth for arrays in the northern hemisphere is true south. The decrease in energy production for off-south arrays roughly follows a cosine function, so if the azimuth of the array is kept to ±20° of true south, annual energy production is not reduced significantly. Some arrays are sited west of south to skew the production toward an afternoon peak load demand.
The expected AC power output from that same 1.2MWdc solar power plant. Notice how the power output varies between each of these three cities. Yes As part of a power plant feasibility study POWER Engineers can help you to estimate the useable power that your system will develop. These graphs take into account Insolation, latitude, tilt angle of PV, PV efficiency, and system losses.



Mounting systems overview: There are many mounting systems available; POWER can help you to find those that are most appropriate for your project needs.

PV mounting systems vary – some are fixed, and some track the sun in a single axis or dual axis configuration. At the average site location, single axis tracking with the PV mounted horizontal can add 15% to 20% output in the summer but will not do as well as a fixed system with the panels tilted toward the south during the winter months. There are many types and manufacturers of mounting systems on the market; each has its advantages and disadvantages.

For instance a generic site in Bakersfield, will have its average yearly irradiance increase from 5.7 kWh/m2/day using a fixed system tilted at latitude, to 7.2kWh using the single axis tracker. Increases in output will occur March thru October but there will be a loss in output of 3 to 4 kWh during the winter months when the sun is low in the horizon.

Next is a partial list of items to ponder when shopping for a mounting system.

PV Mounting Systems

- Does your site location need to meet special building requirements?
- What is the maximum wind speed that it must be designed for?
- What is the maximum snow loading that it must be designed for?
- What structures best use the soil type in your area?
- Can you drive piers directly into the ground or do you need concrete? This will require a geotechnical study of the site and can result in a significant cost savings.
- Can you use a ballasted system?
- What height does your system need to be to avoid being covered by snow, or vegetation?
- If you decide to track, what are the lowest temperatures that system will see?

The type of mounting that should be used will in the end turn out to be an economic decision based on many factors. What does your PV site look like, will it require a lot of civil work? How is your soil, a geotechnical study will tell you if you will need to cement your structural members in the ground or can drive smaller steel. Is there a possible fire or flood hazard, is the land hilly with lots of boulders that may need to be moved using one type of system.

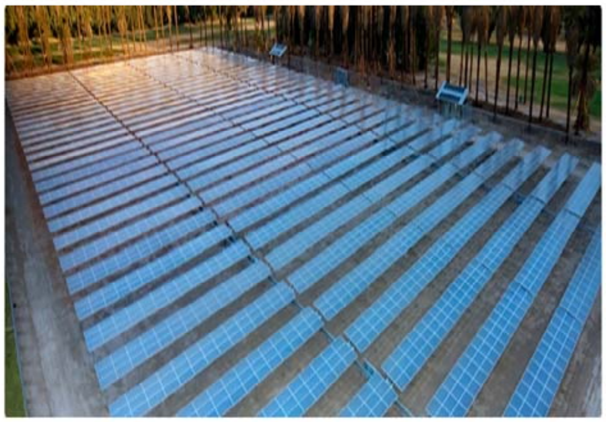
When you are designing a mounting system thought must be given to cable runs and maintenance of the systems. As most trackers are made from mild steel, maintenance of paint is typically required, and may be critical in highly corrosive environments, such as near saltwater or in polluted industrial localities. In regions with extended Summer dry seasons the periodic washing of the panels may significantly increase performance at a critical demand time, particularly for grid-tied systems. Some solar trackers may operate most effectively with seasonal position adjustment and most will need inspection and lubrication on an annual basis.

The most basic tried-and-true system for ground mounting PV is the fixed at latitude system. This system typically has the lowest materials, construction and maintenance cost per panel installed. Fixed PV systems are most productive if the PV modules are mounted close to perpendicular to the sun at solar noon. The best year-round angle for your modules is approximately equal to the latitude of the site. Because the angle of the sun changes seasonally, to increase output in the winter the angle should increase by 15 degrees and in the summer the angle should decrease by 15 degrees. Some ground mount systems allow for the change of angle during the year. A cost analysis should be made comparing the expended labor cost of these angle adjustments to the added output of the system. Typically, the systems are designed to withstand gust wind speeds up to 120 mph. Ground mounting leaves the modules vulnerable to brush growing up in front, rocks kicked up from mowers, and snow having no place to run off unless the system can be elevated. Mounting system Costs for materials and installation labor for fixed systems can be as low as $0.55 per watt if you can use a direct drive pier system with no concrete. As civil work and concrete are added, cost will increase to as much $3 per watt just for the civil and structural work, so picking the right site may be vital to the success of the project.

Single Axis Tracking

There are two main types of single axis trackers. In the first type the PV is horizontal to the ground and rotates east to west following the sun during the day. These units allow row spacing to be closer together allowing for more PV in a given area of land. They do this by backtracking the system in the early morning and evening. Backtracking lays the PV flat in the morning to avoid shading and moves toward the sun as it rises allowing the sun to strike the PV at an angle with no shading. At a point based on the tracking algorithm, the tracker stops backtracking and follows the sun east to west to a point where shading on the adjacent rows will begin to occur. At this point, the backtracking to avoid shading begins again ending with the PV lying horizontal at the end of the day. This is the most common type of tracking in the U.S., with Wattsun, Thompson, Unirac and Sunpower currently being the main suppliers.

Wattsun Tracker:
Individual drive for each row.
Electric screw jack drive
Backtracking controller
Variable spacing between rows
Height can be modified by user
Site welding required



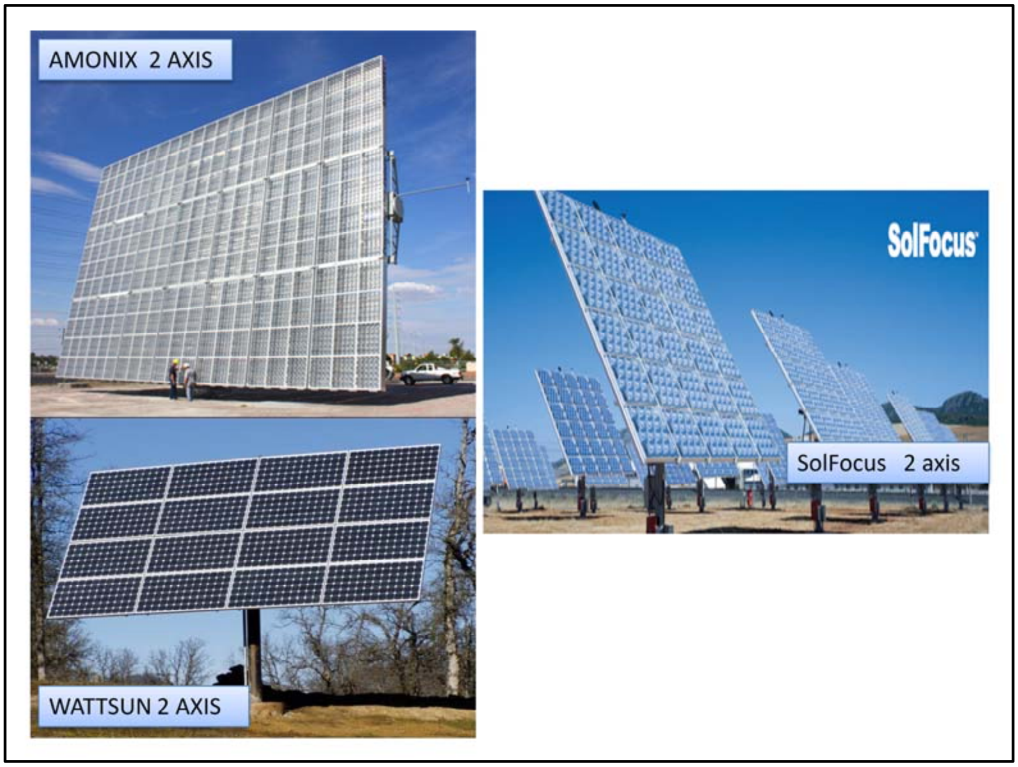
TTi Thompson Tracker:
Single drive for multiple rows
Electric screw jack drive
Backtracking controller
Height limited by size of support columns and Drive support.
Fixed row spacing
Site welding required
Site needs to be flat and level

Because of the changes the power output from a PV array, production can be maximized by keeping the array pointed at the sun. Tracking of the array will increase the energy production in some locations by up to 40 percent for some months and by as much as 25 percent over the course of a year. The most benefit comes in the early morning and late afternoon when the tracking array will be pointing more nearly at the sun than a fixed array. Generally, tracking is more beneficial at sites between 30° latitude North and 30° latitude South. For higher latitudes the benefit is less because the sun drops low on the horizon during winter months. If a wintertime load is the most critical, the fixed or tracking array tilt angle should be set at the latitude angle plus 15° degrees. To maximize summertime production, fix the array tilt angle at latitude minus 15° degrees.

Sunpower Tracker:
Single drive for multiple rows
Electric screw jack drive
Backtracking controller
Height limited by size of support columns and Drive support.
Fixed row spacing
Site welding required
Site needs to be flat and level

Sunpower T20Tracker:
Single drive for multiple units
Electric screw jack drive
Backtracking controller
Height limited by size of support
Fixed row and column spacing
Site welding required
Site needs to be flat and level

Because the sun's position in the sky changes with the time of day as well as with the seasons and solar powered equipment works best when pointed at or near the sun. A solar tracker can make sense to increase the effectiveness of photovoltaic equipment over any fixed position mounting. Trackers are used to improve the amount of time that a PV module is closer to perpendicular to the sun, thus improving the conversion to electricity. Single axis trackers are also a more efficient use of land because they move the PV to avoid shading. This means that their row spacing can be significantly more compact. However, trackers are typically more costly in materials and construction costs as well as in O&M costs. Trackers have parasitic loads that are usually not taken into account when system performance is calculated, but which will show up in the site metering.



The use of trackers in non-concentrating applications is usually an engineering decision based on economics. Compared to the photovoltaics, trackers can be inexpensive. This makes them especially effective for photovoltaic systems using high-efficiency (and thus expensive) panels. Tracking can substantially improve both the amount of total power produced by a system and that produced during critical system demand periods (typically late afternoon in hot climates. Maintenance costs will be greater than fixed systems because of the inclusion of moving parts into the system.

Dual axis solar trackers also called azimuth trackers are typically trackers that rotate on a single mounting pole and track the sun all day long from sunrise to sunset. They have the capability to exploit all the available solar power available. A typical drive for these systems constitute one linear motor and one worm gear motor system working together. Typically tracking systems require more maintenance and are more susceptible to the elements than fixed systems. Dual axis systems will also require more land area on larger sites than a fixed system due to shading issues. However the site does not have to be graded level, single pole mounting can be made in almost any soil type and may not even require cement, resulting in a significant construction cost savings. Grounding individual trackers rather than an entire field will also create a good savings.

Typical dual axis tracking results in improvements of 20 to 24% in the Winter and up to 42% in the Summer over a fixed system. In other words a fixed system will need 40% more panels to match the annual of a dual axis tracker. Much of this full output is late in the afternoon hitting some of the time of day special pricing. The tracked array delivers peak output for about ten hours and the fixed array peaks for only two hours or the tracker provides maximum output from 7:30 to 5:30 while the fixed array only peaks from 11 to 1, or five times longer.

Your roof top is valuable real estate, without the permitting problems associated with brownfield installations

Unirac PV roof mounting system
Accepts most standard PV
Roof loading dependent on tilt angle
From 2 lbs/ft 2 with penetrations to a ballasted system with no penetrations.

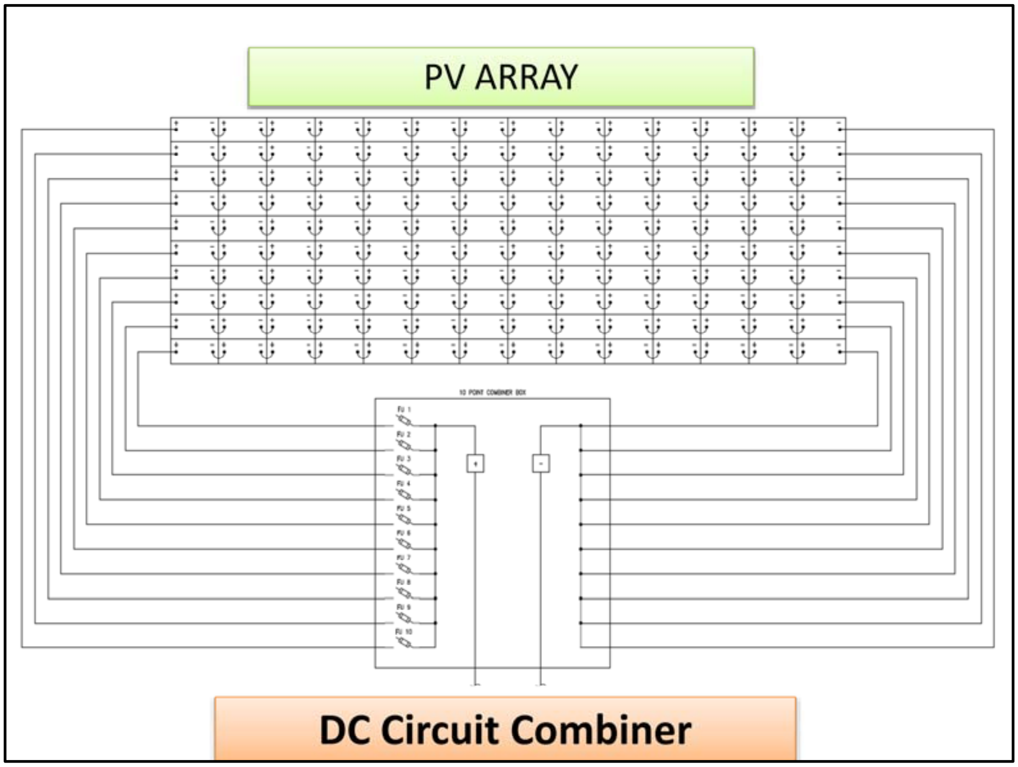
Examples of Roof Top Installs

Courtesy of Sunlink

Distributed weight	2.5–3.2 PSF
Tilt angles	5°, 10°, 15°, 20°
Roof applications	BUR; PVC; TPO; SMS; virtually any flat roof
Warranty	15 years
Materials	All aluminum construction, stainless steel fasteners

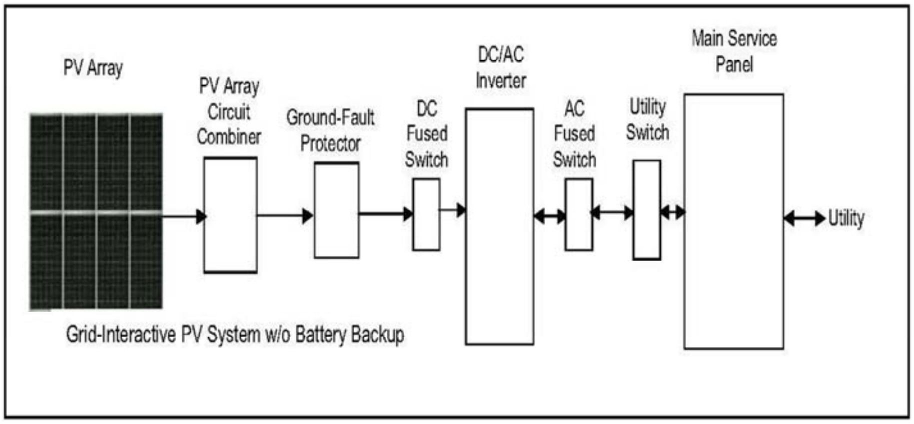
Phizer = KW 337 Tilt Angle 5 deg.

Number of Modules 1,372 Model Sharp



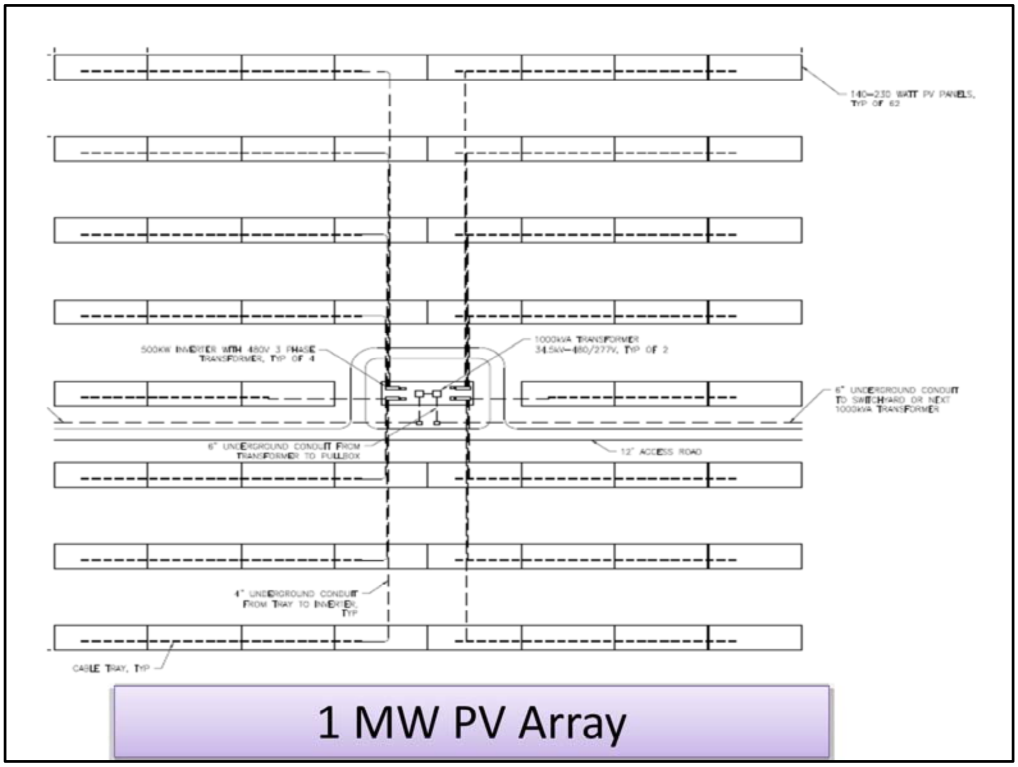
This array shows 14 modules in series to form 10 strings in parallel combined into a two wire DC feed to an inverter.
A number of pv panels in series is termed a string
A number of strings in parallel is called an array
Depending on the desired capacity of the PV system, there may be several PV strings connected in parallel to achieve higher currents and subsequently more power. PV systems that have three or more strings connected in parallel will need to have each string protected by a fuse. This fuse will protect the conductors from damage and help minimize any safety hazards. It will also isolate any faulted string so that the rest of the PV system can continue to generate electricity. On a large sites, array combiners similar to Circuit combiners, may be used to combine the power from several arrays. A system design should include an economic vs. power loss study for combining your DC circuits. The National Electrical Code specifies the types and sizes of conductors and the over current protective devices. Most of the new combiners use touch or finger-safe fuse holders for grounded systems (UL) or for floating systems (CE). Some of the new features inside DC combiners that are coming on the market include intelligent string management. This system improves solar array management by sensing current at the string level. Performance data at the string level is a valuable tool to PV owners as it enables the quick diagnosis of system level underperformance due to failed modules, connections or soiling. The comprehensive diagnostic capabilities can identify string-level connection and performance issues. These systems can also feature multisensor temperature monitoring and can transmit data to the PV inverter using a RS-485 Modbus connection. Many have alarming functions that can alert the owner to problems so that repairs can be made, others may contain reports functions so that production and be viewed over time.

Typical Installation



As was stated earlier the voltage output of a Solar Panel/Array is defined by the number of individual cells in series. An individual panel is made up of a series string of photovoltaic cells. Globally there is a push for utilizing higher voltages (trending to 1000Vdc and above). The vast majority of large Solar Farms in North America are 600Vdc, but following the lead from Europe we are seeing the use increase voltages up to 1000Vdc to achieve more efficiency.

A number of pv panels in series is termed a string, and the number of strings placed in parallel is called an array. The output of the array is set by the input requirements of the inverter.



Whether you have one inverter or many you now need to tie that output into the power lines or substation in order to use or sell the power generated. A collection system can be as simple as transforming the 480VAC output of the inverter to the local electrical distribution system voltage and taping into the line, to transforming multiple inverter outputs into a collection system substation complete with breakers, protection and Buss work. Photovoltaic systems typically are land intensive with a 1MW site taking 8 to 10 acres of land. Because of this sites over 1MW need to look at transforming the low voltage output of inverters to a medium voltage allowing for smaller cables or more inverter outputs per cable. Higher voltages will also reduce losses due to cable resistance and if the system is sized correctly can reduce the cost of transforming to the grid voltage.

In order to tie small systems 5-20MW into the grid an interconnection agreement will need to be filed with the local grid operator. They will perform a set of studies at your expense that will determine whether your site will overload the power lines. The studies will identify any potential impacts to their system or financial impacts to you as the developer. In California, a Small Generator Interconnect (SGIA) can cost about $20,000 and take 6 months to get the approval to tie into the grid. Anything over 20MW is considered a Large Generator Interconnect (LGIA) and to file in California will require a deposit of $250,000 and may take 3 years to get approval. Medium voltage collection systems, collection substations and high voltage interconnects require the experience and expertise that can be found at POWER and should be taken advantage of.

One Size does not fit all:
A Solar Inverter is an electrical device that converts the photovoltaic array Direct Current (DC) to Alternating Current (AC). The inverter DC input requirements set the allowable range of DC voltage that the PV field may generate.
The AC output from the inverter can be allmost any standard voltage and frequency. Grid-tied inverters automatically match the phase with the grid-supplied sine wave and are designed to shut down automatically with the loss of the grid supply. If the inverter does not shut down this is called "islanding." Standard anti-islanding protection comes with all new IEEE 1547-rated inverters. PV inverters use a technique called Maximum Power Point Tracking (MPPT) in order to provide the most kilowatt power from a PV array. This internal circuit defines the amount of current that the inverter should draw from the PV strings in order to get the most AC power output.

A site designer will consider whether there is a cost savings in using 1 x 1MW, 2 x 500 kW or 4 x 250kW inverters for a 1MW block of PV and determine the tradeoff in production losses if a failure results.
Inverters if not housed inside a controlled environment may require a wide thermal operating range: -40º C (-40º F) to 85º C (185º F) and they should be able to tolerate high humidity and air-pollution levels. There may be a required seismic rating for your site location, if so that needs to be looked at also.

What to look for:
Some of the items that a designer should look for in an inverter that will make construction and maintenance faster and less costly are a single cabinet with convenient access to all components, large in-floor cable glands to make access to DC and AC cables easy. Is it engineered for outdoor environments? Are their remote monitoring and faults notification via various communication options. Some Inverters can be ordered with a output transformer to provide a medium voltage output that will accommodate long-distance power feeds to designated loads or substations. The selection of the inverter should be tied to the design of both the DC string voltage and the AC collection systems as well as the grid interconnect system. Some inverters can be purchased to save the cost of DC combiners, or may be designed to help with costly reinforcements to the grid that may be required. Inverters should undergo testing and certification such as - UL1741, CSA 107.1-01, IEEE 1547, IEEE C62.41.2, IEEE 62.45, IEEE C37.90.1, IEEE C37.90.2 and CE Certification (EN 50178, EN 61000-6-2, EN 61000-6-4) depending on their use and location.

Something to keep in mind is the ever changing rules and guide lines that are being reviewed and may be created for large scale PV plants such as the need for a PV site to generate VARS.
An example of other recommendations for change can be found in the NERC report: Accommodating High Levels of Variable Generation - dated April 2009

"PV plants with ratings on the order of hundreds of MW are being proposed throughout the North America. It is unclear if the scale of these plants will limit the impact on ramping by virtue of significantly greater land coverage. PV connected at distribution levels, e.g. residential and small commercial installations are subject to IEEE Standard 1547. This standard prohibits distributed generation, including PV, from riding through grid disturbances involving significant voltage or frequency excursions, and also prohibits providing voltage control.38 Thus, widespread deployment of small distribution connected variable generation has the potential to have adverse impacts on grid performance. Evidence of this problem is starting to surface in some small grids now. Further evolution and reconciliation of IEEE 1547 to take broader grid performance considerations into account is needed."
This means that the inverter that is specified today may not meet the new standards of tomorrow, so it is necessary for all of us to keep abreast of the ever changing environment as PV grows to maturity.

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The small 300kW Photovoltaic systems of the past required little in the way of engineering and design. Usually used for load shedding or powering small off grid systems little engineering skill was required. Now with the PV systems growing in size, while appearing simple on the surface have become quite complex and require a balance of high-quality economic and engineering skills in their design. The typical 1-2% of project cost that is engineering can save large amounts in construction costs and boost production reducing payback time. A good engineering company is your friend, take advantage of their skills when planning a power project.