Solar Photovoltaic (PV) Site Assessment

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Introduction

An important consideration when installing a solar photovoltaic (PV) array for residential, commercial, or agricultural operations is determining the suitability of the site. A roof-top location for a residential application may have fewer options due to limited space (roof size), type of roofing material (such as a sloped shingle, or a flat roof), the orientation (south, east, or west), and roof-mounted structures such as vent pipe, chimney, heating & cooling units. A location with open space may utilize a ground-mount system or pole-mount system.

Determining the physical location of a solar PV array is a critical step to optimize energy output performance of the system. The ideal location is where solar modules are exposed to full sunshine from sun up to sun down without worry about shade cast on the modules from trees, power poles, guide wires, vent pipes, or nearby buildings, or the changing location of the sun. In the Northern Hemisphere, solar PV arrays are oriented to the south toward the Equator. Over the course of a calendar year, the sun's altitude (height) in the sky changes. For example, during the month of June, the sun reaches its highest point in the sky on June 21 at 12:00 noon (summer solstice), and the sun is at its lowest point in the sky on December 21 at 12:00 noon (winter solstice).

The solar industry uses the phrase "solar azimuth angle" which is the sun's horizontal position and is measured in degrees east or west of true south (180 degrees). For example, if the sun is located 35 degrees west of true south, the solar azimuth angle is 215 degrees (180 + 35 = 215).

The sun's vertical position in the sky is referred to as the "altitude angle" and is measured in degrees above the horizon. At sunup or sundown, the altitude angle would equal 0 degrees. At 90 degrees altitude, the sun would be directly overhead. When the sun is located at 180 degrees (true south), the sun is at its highest altitude angle of the day. This is referred to as "solar noon."

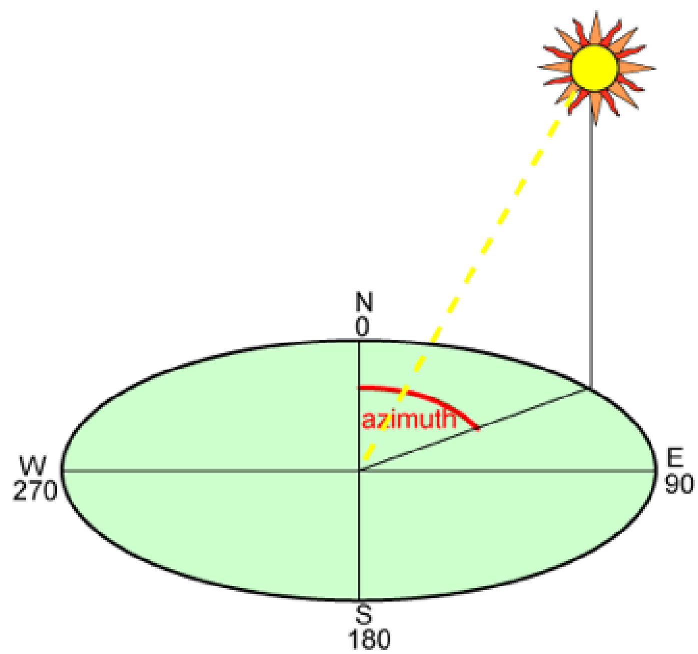


Figure 1. Solar azimuth angle. Source: www.pveducation.org

Sun charts (such as those available from the University of Oregon's Solar Radiation Monitoring Laboratory (http://solardat.uoregon.edu/SunChartProgram.html) can be created for a particular geographic location based on the latitude and longitude of the proposed site. The sun chart reveals the path the sun travels across the sky from dawn to sunset on an hourly interval and on the 21st day of each month. The chart displays the changes in altitude angles (0 to 90 degrees) and solar azimuth angle (from 60 degrees --- east of true east --- to 300 degrees --- west of true west). This information is used by an installer to orient the array towards the location of the sun when it is at its highest angle in the sky and when to make adjustments

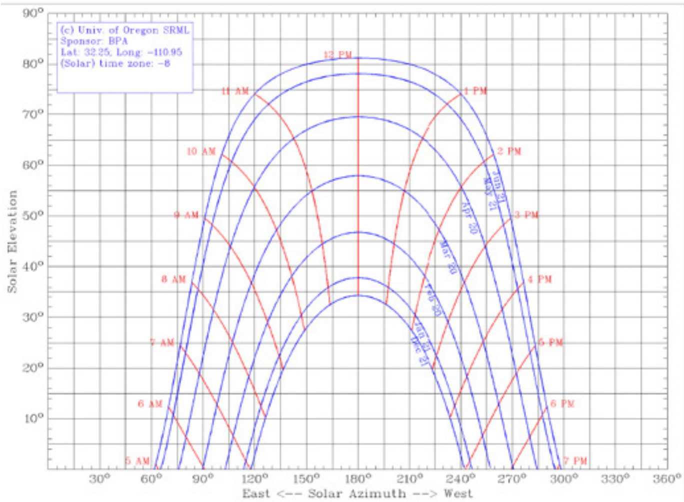


Figure 2. Sample solar chart for Tucson, Arizona
Source: Solar Radiation Monitoring Laboratory, University of Oregon

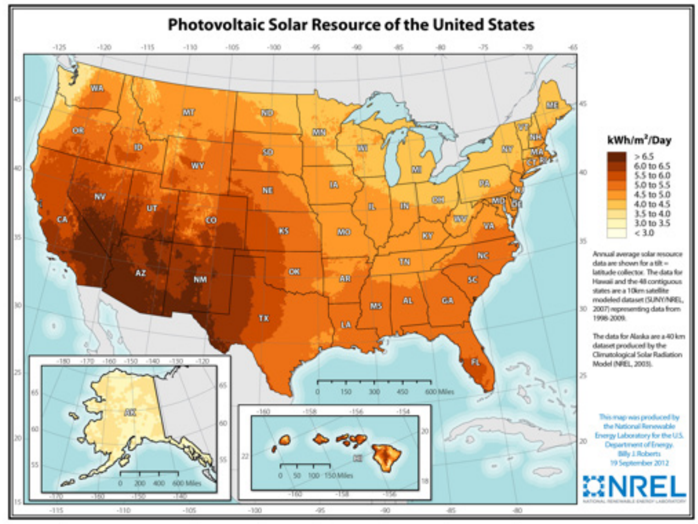


Figure 3. A map of peak sun hour values, measure in kilowatt hours per square meter per day. The higher the value, the longer sun is shining during a 12-hour period.
Source: National Renewable Energy Laboratory (NREL)

Peak Sun Hours

To estimate the energy a PV array will produce, it is important to know how much sun the array will receive. During the winter months, the days are shorter and the amount of actual sunlight is less than during the longer days of the summer months. Peak sun hours is the average of the daily amount of sun available for a particular location. Sunlight intensity changes over the period of a day so the total amount of energy received from the sun over the day is summed. The total is converted to the number of hours the sun would have to shine at 1,000 W/m2 to provide the same amount of energy. For example, 4 peak sun hours = 4 kWh/m2 total for the day, even though the sun may have been shining at varying intensities for 10 hours or more. In the southwest region, the peak sun hours will be highest during the months of April to August and lowest during the winter months of November to February.

Energy from the sun in a geographic location can be measured in peak sun hours. This value is an average of the amount of time the sun is shining during a 12 hour period. In the southern states the peak sun hour values are higher than in the northern states. For example, peak sun hours in Tucson, Arizona range from 3.9 to 7.8, depending on the tilt angle and the month of the year. The National Renewable Energy Laboratory (NREL) map of Photovoltaic Solar Resources of the United States (figure 2) represents the average peak sun hours (PSH) by states. The darker colors represent higher PSH values. According to one solar energy source, the state of Arizona has peak sun hours of 7-8 (Renology, 2015).

A peak sun hour chart developed from weather data shows average daily peak sun hours available for a specific location by month. Charts are available from the National Renewable Energy Laboratory (www.rredc.nrel.gov/solar/pubs/redbook/) for fixed plate arrays which give the average peak sun hour per month and average per year, by latitude and latitude +15 and -15 degrees. The daily average for a southwest location in July would be the highest, and the lowest monthly average would be during the month of December.

Module Tilt & Orientation

Ideally, the solar PV module is set at a perpendicular angle to the sun when the sun is at its highest point in the sky during the day. The ideal module installation tilt angle is the same as the latitude of the geographic location. For example, a module located in Tucson, Arizona would be installed at a tilt angle of 32 degrees. As the location of the sun changes, the power output changes. Referencing a fixed plate collector table (Figure 4) the peak sun hours value increases and decreases. At latitude, the peak sun hour value decreases during the fall and winter months, and increases during the spring and summer months. If the tilt angle of the module or array can be adjusted, lowering the module 15 degrees (to 17 degrees) during the summer months because the sun is higher in the sky, and increasing the tilt angle 15 degree (to 47 degrees) during the winter months, because the sun is lower in the sky, will keep the module at a perpendicular angle to the sun. Orienting the module to a south-facing direction will increase the output of the module. Unfortunately, a roof-mount or ground-mount array may not be adjustable due to its fixed mounting. In this case, leaving the array at tilt angle of latitude (32 degrees for Tucson, AZ) will suffice. In the table below, a module or array mounted in a fix position at latitude (32 degrees), the average peak sun hours for each month is listed. For January, the peak sun hour (PSH) value is 5.4. This value increases each month

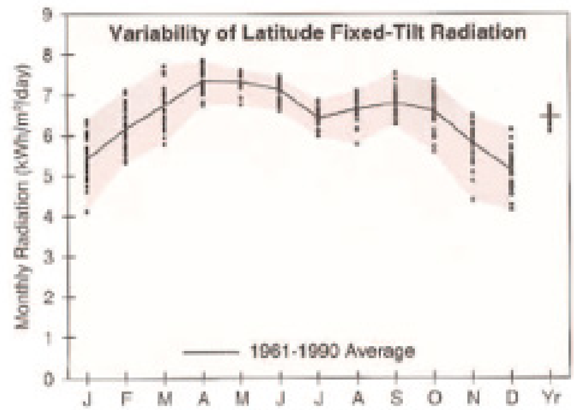
Table 1. Fixed-tilt angle of solar PV collectors for latitude of 32 degrees in Tucson, AZ.
Source: National Renewable Energy Laboratory

Tucson, AZ

WBAN NO. 23160

LATITUDE: 32.12° N
LONGITUDE: 110.93° W
ELEVATION: 779 meters
MEAN PRESSURE: 925 millibars

STATION TYPE: Primary



Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	3.4	4.4	5.6	7.1	7.9	8.1	7.1	6.7	6.0	5.0	3.8	3.2	5.7
	Min/Max	2.8/3.9	3.9/4.9	5.0/6.3	6.5/7.6	7.3/8.2	7.4/8.6	6.5/7.6	5.8/7.2	5.5/6.6	4.4/5.4	3.1/4.2	2.7/3.6	5.5/5.9
Latitude -15	Average	4.6	5.5	6.4	7.5	7.8	7.8	6.9	6.9	6.6	6.1	5.0	4.3	6.3
	Min/Max	3.6/5.4	4.8/6.3	5.6/7.3	6.8/8.0	7.2/8.1	7.2/8.3	6.4/7.4	6.0/7.4	6.1/7.3	5.2/6.7	3.9/5.6	3.6/5.1	6.0/6.5
Latitude	Average	5.4	6.2	6.7	7.3	7.3	7.1	6.4	6.6	6.8	6.6	5.8	5.1	6.5
	Min/Max	4.1/6.4	5.3/7.1	5.8/7.7	6.7/7.8	6.8/7.6	6.6/7.5	6.0/6.9	5.8/7.1	6.3/7.5	5.6/7.3	4.4/6.5	4.1/6.1	6.1/6.7
Latitude +15	Average	5.9	6.4	6.6	6.8	6.4	6.1	5.6	6.0	6.6	6.8	6.2	5.6	6.3
	Min/Max	4.4/7.0	5.5/7.5	5.7/7.7	6.3/7.3	6.0/6.7	5.7/6.3	5.3/6.0	5.3/6.4	6.0/7.3	5.7/7.5	4.6/7.0	4.5/6.8	5.8/6.5
90	Average	5.2	5.1	4.4	3.5	2.5	2.1	2.2	2.8	4.0	5.1	5.3	5.1	3.9
	Min/Max	3.8/6.3	4.3/6.0	3.7/5.1	3.3/3.6	2.4/2.6	2.0/2.1	2.1/2.2	2.6/3.0	3.6/4.3	4.2/5.7	3.8/6.1	4.0/6.2	3.6/4.1

and reaches the highest value during the months of April and May (7.3). If the module or array tilt is adjusted to a lower position (latitude – 15 degree) during late spring and summer months, the PSH values are higher (7.8) than the values if the array position is left at latitude. During the fall and winter months, if the tilt is increased (latitude + 15 degrees) the PSH values are higher. To determine if making the tilt adjustments is worth the difference in energy the output, the PSH values are entered into a calculation to determine total PV system output.

Generally, in the Northern Hemisphere, setting a module or array to a fixed-tilt of 30 degrees will be satisfactory for year-round production for a grid-connected array (a system sending power to a local utility) when it is not feasible to adjust the tilt.

A module or array set at a horizontal (0 degree) angle, or flat is subject to losses from accumulated dust, dirt, or possibly snow build-up and require attention or maintenance. A tilt of 90 degrees (vertical) does not take advantage of full exposure to the sun, especially during summer months so the output performance is less.

Tools

There are a number tools used to conduct a solar site assessment. The tool used to measure solar irradiance (sunlight intensity) is a pyranometer. Irradiance is measured in units of watts per meter squared (W/m2). On a bright, sunny day between the hours of 10:00 AM and 3:00 PM, sunlight intensity will measure about 1,000 W/m2. See figure 4.

Figure 4. A solar irradiance meter (pyranometer) is used to measure the light intensity of the sun when the end of the meter is directed at the sun. Solar module power values are based on an irradiance level of 1,000 W/m2.
Source: Author

Figure 5. An inclinometer is set on the frame of the module and gives the tilt angle in degrees when the module is raised or lowered.
Source: Author

This value is a part of the Standard Test Conditions (STC) and used to measure the output performance of a solar PV module. In other words, a 20-watt solar PV module rated at 17 volts is used to energize a DC submersible pump to move water, and a digital multimeter is used to measure the DC volts, the expectation is the module is producing 17 volts. If the meter value is 500 W/m2, the anticipated voltage output may be at half the value (8.5 volts) because the sunlight intensity is lower (50%) than when sunlight is at full intensity.

To measure the tilt angle of the solar PV module, an inclinometer is placed on the surface of the frame of the module and the angle is read in degrees. The latitude of the geographic location is used for the tilt angle, as this provides a perpendicular angle to the sun when it is at its highest point in the sky. See figure 5.

An azimuth compass (figure 6) is used to locate a direction of south from the proposed site. This is the ideal direction to orient the module. However, environmental and seasonal weather conditions may force the installation to be adjusted to a more southwesterly orientation (230 degrees) to take advantage of afternoon sunshine. Additionally, rooftop orientations of east or west limit the installer. The choice between an east- or west-facing roof installations can be determined by size of area free of obstructions, and environmental conditions. Cooler temperatures in the morning result in cooler modules. But at least five hours of sun exposure should be a consideration of determining whether one side is better than the other.

A Solar Pathfinder is a tool used in site assessment to determine the amount of shading at a particular site. The device allows the user to determine where shading will be an issue for a 12-hour

Figure 6. An azimuth compass is used to determine the best orientation for a PV array.
Source: Author

period over 12-months. The lower the percent shading, the better the site. The tool is set up at each corner of a proposed array location. A sun chart for the latitude of the location is inserted into the pathfinder. A 360-degree view of the site from the pathfinder reveals where structures surrounding the site, such as trees, shrubs, walls, buildings, poles, etc. may produce shade at different times of the day and days of the year. A white chalk-like pencil can be used to trace the shading pattern on the sun chart. Numerical values for times of day and months of the year are summed and a shading percentage is calculated for the site. On a roof-mount array, the tools is set up all four corners of the array. In figure 7, the silhouette of trees can be viewed on the right side (west) of the sun chart.

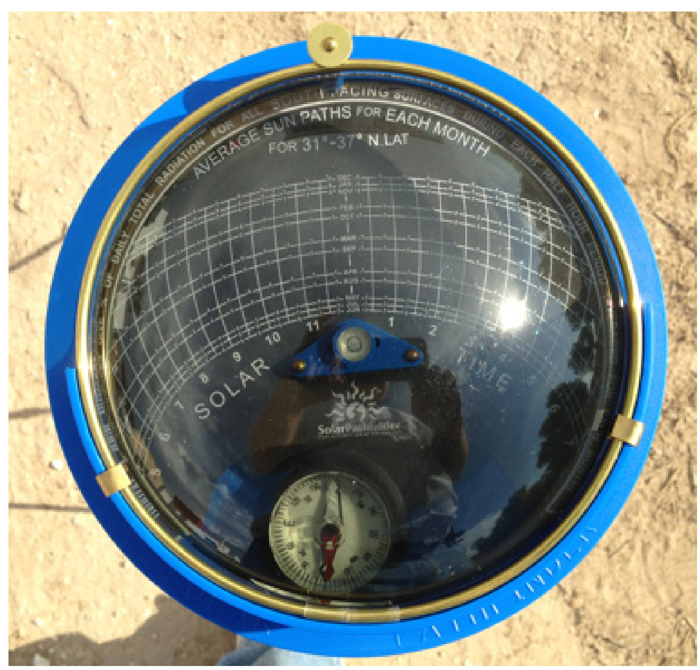


Figure 7. A Solar Pathfinder™ can determine where shading will come from surrounding a site and the amount of shading over the course of a year and at times of day from 6 AM to 6 PM.
Source: Author

Conclusion

The decision to place a solar PV array is a consideration of multiple factors which include location, space, system size, and system type. Having a basic understanding of how the location of the sun impacts the performance of the solar PV module or array can aid the solar PV system owner to make sound decisions which result in achieving optimum solar PV system performance.

A recommended source for the solar enthusiast and do-it-yourselfer is a publication called Home Power Magazine. Articles are written by renewable energy industry experts in a non-technical style and include multiple photographs and diagrams. In addition to solar PV topics, the magazine covers a wide range of renewable energy topics (solar thermal, wind energy, micro-hydro, geothermal, bio mass, biodiesel, etc.).

References

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