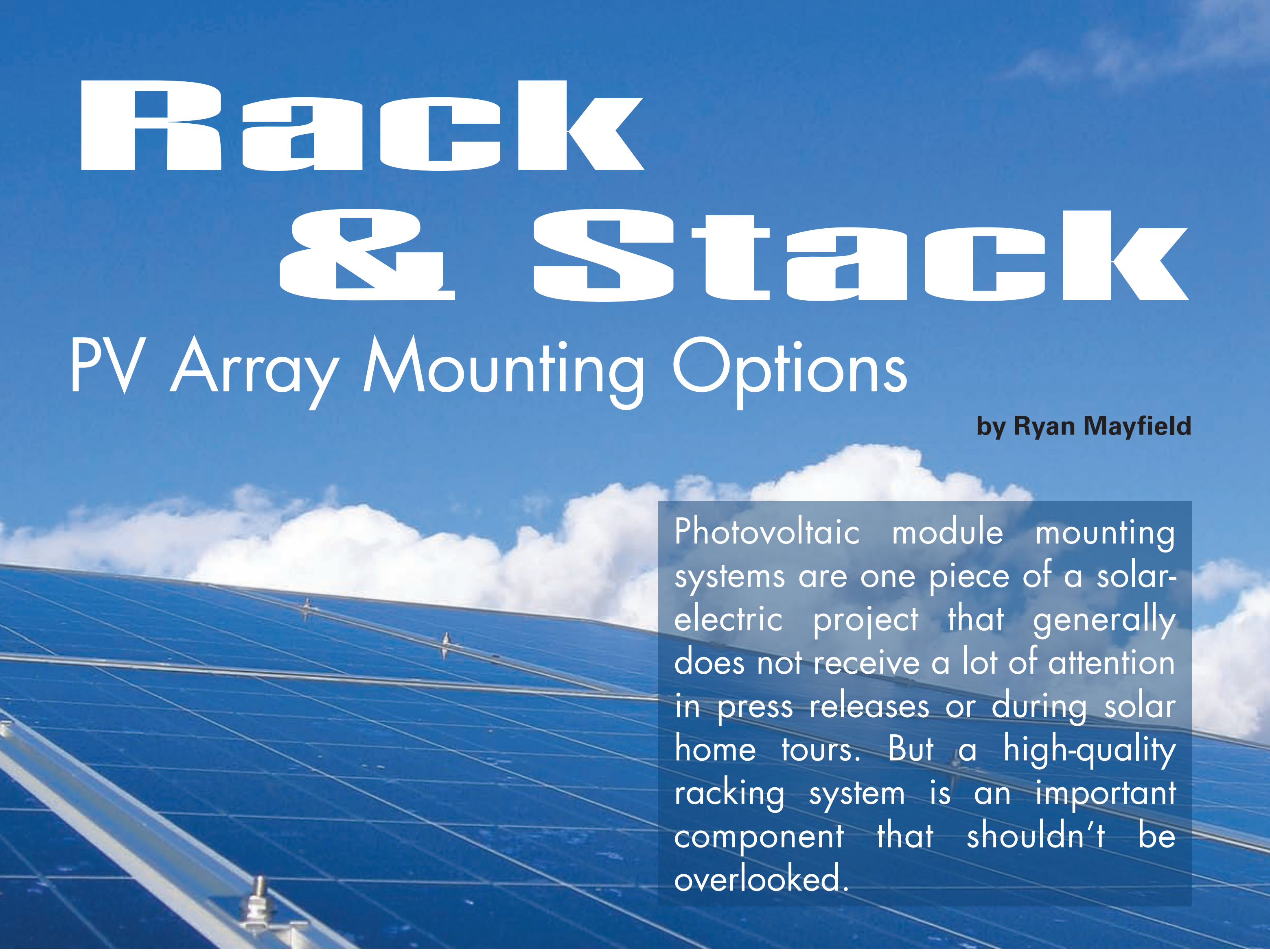


Rack & Stack

PV Array Mounting Options

by Ryan Mayfield

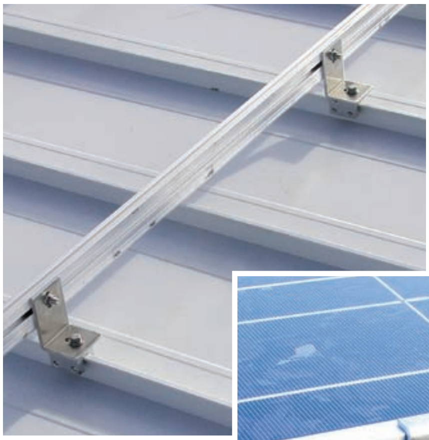
Photovoltaic module mounting systems are one piece of a solar-electric project that generally does not receive a lot of attention in press releases or during solar home tours. But a high-quality racking system is an important component that shouldn't be overlooked.

For most PV applications, gone are the days of having to custom-manufacture a mounting system. Many commercially available solutions exist—from pole-top module mounts to rooftop rails. This guide will help you navigate the variety of options available today and their associated advantages to fit your specific application.

Top-Down Rail Systems

One of the most common—and very popular—PV module mounting methods is the "top-down" rail system, since modules attach from their upper side to the rails with specified clamps. This versatile system can be used with almost all roofing types. Top-down mounting systems consist of four main components:

- Feet or posts (also called "footings" or "stand-offs") that are typically secured to the roof's rafter system;
- Extruded aluminum rails fastened to the feet or posts and the array;
- End-clips that secure the ends of the PV array to the rails;
- Mid-clips that hold the junction of two modules to a mounting rail.



Top-down rail mounts are popular in both home- and business-scale installations.

Mounting clips attach PV modules to the rails from the top, allowing quicker installations.

Manufacturers of top-down rail systems each take their own approach, with slight nuances on the same basic mounting principles. Mounting rails are extruded lengths of aluminum which allow installers to use standard or mount-specific stainless-steel bolts and mounting clips to attach the PV modules to the rails.

Top-down rail systems offer several advantages for roof-mounted PV arrays. The first is that the array is mounted parallel to the roof plane, which minimizes the array's visual impact compared to other mounting options. Second, the PV modules are attached to the rails from the *front* side, instead of the back, which decreases installation time. Many top-down rail manufacturers have also developed integral array equipment-grounding options.

The adjustable spacing of the footings and rails also offers a flexible design element. Since the feet can be attached to the rails at any place along their length, the exact footing location is inconsequential as long as the spacing between each does not exceed the manufacturer's recommendations. In a top-down system, PV modules can either be placed in a portrait or landscape configuration to accommodate a particular roof's characteristics. Although the rails are generally mounted perpendicular to the rafters, when necessary the rails can be run parallel to the rafters.

The downsides? Rail systems typically result in only 3 to 6 inches of space between the back of the modules and the roof surface. Although this space does allow for some airflow underneath the array, modules mounted this

Courtesy www.conergy.us

Conergy's SunTop rail system offers a flexible, top-down mounting approach for a wide range of roofing materials.

Courtesy www.sharpsolaritson.com (2)

Sharp's top-down mounting rails are one component of their SRS system kits.

Courtesy www.unirac.com

UniRac's module clips used in conjunction with S-5! clamps to mount an array directly to standing-seam roofing.

Courtesy www.electronconnection.com

A DP&W rack sets an angle steeper than the roof pitch. Fixed-pitch and adjustable racks are available.

close to the roof surface tend to reach higher temperatures (more so compared to most other mounting options), which diminishes the amount of power delivered from the array (see "Module Mounts & PV Performance" sidebar). Besides the negative effects of temperature on the array, access to the back of the modules is greatly reduced. However, since the majority of modules are prewired with quick connects and inaccessible junction boxes, access to the backs of the modules will only be necessary if troubleshooting is required. Finally, when the PV array is mounted parallel to the roof's surface, the *roof* dictates the array's tilt angle. Less-than-optimal tilt will result in less-than-optimal performance from your PV array.

Rack Mounts: Adjustable- & Fixed-Tilt

Rack mounts can be tailored to fit a variety of situations, accommodating both ground-mount and roof-mount applications. Perhaps the biggest benefit to racks is that they can allow for a variety of specific tilt angles. The PV array can be set at an optimal tilt angle based on the site's latitude or, if adjustable racks are chosen, repositioned seasonally to optimize energy output.

The back-leg assembly of adjustable rack mounts can either be set to hold the array at a fixed tilt or to be manually adjusted. When an adjustable tilt is required, the tilting legs are manufactured with predrilled holes or slots that correspond to different tilt angles, or with telescoping legs that have specific tilt-angle attachment points or, in some cases, are infinitely adjustable.

Since these mounts tilt the array away from the mounting surface, the backs of the modules can usually be conveniently accessed to get to the wiring, junction boxes, and grounding points, making installation and maintenance easier. The increased distance from the mounting surface also facilitates greater airflow along the back of the modules and results in a lower array temperatures compared to the parallel-to-roof method.

These racks offer a lot of versatility: The same rack can be used for a ground- or roof-mounted array, or even in an awning configuration on the side of a building. The footing attachments also vary, although aluminium angle L-feet and post-type mounting feet are the two most popular options. Some rack mounts are designed for top-down module installation, while others require the modules to be secured from the back. In the latter case, the predrilled holes on the back of a module's frame are used to fasten the PV modules to the rails.

Rack-type mounts have a few disadvantages. Many designs require ordering a specific rack with mounting-hole spacing that matches the PV module's mounting holes. In roof-mounted systems, rack mounts have less layout flexibility than top-down rail systems. Most rack mounts have a fixed distance between the mounting feet based on standard rafter spacing of 24 inches. If the rafter spacing was poorly laid out or based on a nonstandard pattern, adding blocking against the underside of the roof sheathing between the rafters may be required. Finally, rack mounts tilted to angles that significantly differ from a building's roof pitch tend to have a greater aesthetic impact on a building than arrays that are mounted parallel to the roof surface.

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A rack-style mount used in an awning configuration.

Courtesy J. Sanchez

Module Mounts & PV Performance

PV system owners get very excited about the number of kilowatt-hours produced by their systems. And for good reason—this electricity is helping to offset their utility bills or, in off-grid scenarios, providing most or all of their electricity. Anything that can help or hinder production should be investigated, and racking methods are no exception.

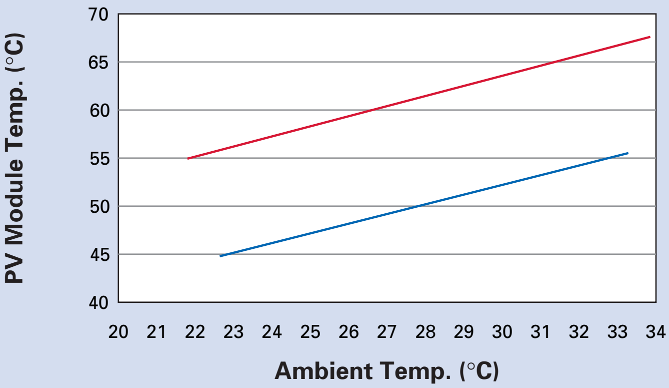
Frank Vignola and his team at the University of Oregon's Solar Radiation Monitoring Laboratory have been collecting environmental and PV system performance data across the Pacific Northwest (see http://solardat.uoregon.edu). This data has enabled PV designers to accurately predict PV array output for a variety of installation conditions—including mounting methods.

Because high temperatures adversely affect a PV system's performance, it's particularly important to try to implement best practices when feasible. In general, arrays that are mounted parallel to the roof surface with less than 6 inches of space between the array and roof will experience cell temperatures of about 35°C (63°F) above ambient temperatures. For rack-mounted arrays, where the back of the array is tilted off the roof surface greater than 6 inches, cell temperatures are estimated to be about 30°C (54°F) above ambient. Top-of-pole mounted arrays will operate at approximately 25°C (45°F) above ambient temperatures. In general, PV array output takes a 0.5% hit for every 1°C rise in temperature.

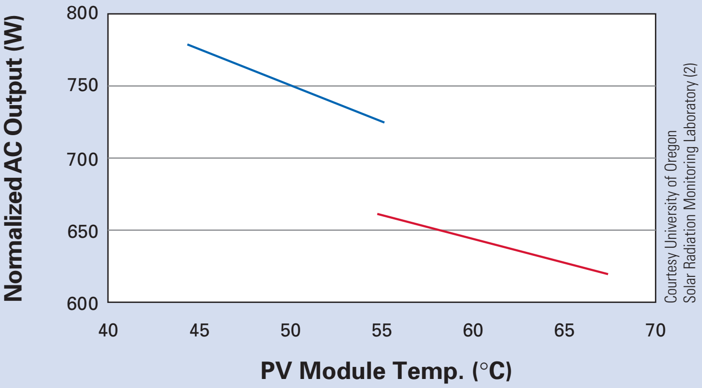
Two other critical array mounting concerns for optimizing system production are the array's orientation (relationship to true south) and the tilt (the array's angle off of horizontal). As a general rule, for a fixed array to produce the maximum amount of energy annually, it should be oriented toward true south (after correcting for magnetic declination), with its tilt angle fixed to correspond to the site's latitude.

However, this general approach can be fine-tuned based on site specifics such as what time of year the most potential solar energy is available, or if the interconnection agreement with the utility is based on annual, rather than monthly, system output. For locations in western Oregon, for example, an array will produce the most energy when oriented slightly west of south at a tilt angle of approximately 30 degrees (approximate latitude minus 15 degrees). In the eastern half of the state, where there is a greater solar resource, the ideal array position is approximately a 35-degree tilt (approximate latitude minus 10 degrees) and either a true south or slightly east-of-south orientation.

Rack Style & Module Temperature



Module Temperature & Performance



Rack Mount (Eugene, OR) — Parallel-to-Roof Mount (Bend, OR)

The above graphs are based on two different arrays: one in Bend, Oregon, mounted parallel to the roof plane and 4.25 inches above the roof surface, and another in Eugene, Oregon, mounted at a 30-degree angle to a flat roof. For the comparison, only data obtained with incident solar radiation between 900 and 1,000 watts per square meter was used. Data was grouped into four "bins" with ambient temperature between 20 and 24°C, 24 to 28°C, 28 to 32°C, and 32°C and above. The data is represented by trend lines. Exact system performance will vary with local conditions.

The Module Temperature & Performance graph shows the approximate 0.5% decrease in output per 1°C increase in module temperature at each site. The Rack Style & Module Temperature graph illustrates the temperature advantage to mounting PV modules away from the roof plane to increase air circulation and cooling. The modules mounted at a 30-degree angle to the roof stayed about 12°C cooler and performed about 6% better than those flat-mounted 4.25 inches above the roof.

Pole mounts allow easy tilt adjustment and snow clearing, and ample air circulation means cooler modules for more power output.

Top-of-Pole Mounts

The top-of-pole mounting solution is a favorite among many installers for a variety of reasons. The ability to locate an array far away from shading objects, to tilt and orient the array in an ideal position, and to avoid punching a bunch of holes in a customer's roof are all positives. With the advent of high-voltage string inverters, and MPPT controllers that can step down higher-voltage PV arrays to a lower battery charging voltage, pole mounts can be located up to a few hundred feet from the charge controller or inverter. Top-of-pole arrays are viable for locations with enough land space and where possible aesthetic concerns are not an issue.

Depending on the size of the array, the support pole can be as small as 2-inch-diameter schedule 40 steel pipe to 8-inch-diameter schedule 80 for large arrays. The footing for the pole is encased in concrete according to manufacturer's specifications (or local engineering) for the array size and the site's soil and wind-loading conditions. In these setups, the top of the array is generally too high to be easily accessible and a ladder or scaffolding system will be required during installation.

With the exception of the actual pole, which is purchased locally, the mount manufacturer provides all the necessary components and hardware to mount the array. Included are the mounting sleeve, which slips on top of the pole, and all necessary bracing and cross members, as well as module mounting hardware. (See "How to Install a Pole-Mounted Solar-Electric Array: Part 1 & Part 2" in *HP108* & *HP109* for pole-mount installation specifics.)

The ability to adjust the array tilt seasonally is a natural function of any top-of-pole mount. This can be of particular interest for off-gridders who rely on every KWH of electricity produced by their PV systems. In cold climates, top-of-pole mounts are one of the most convenient racking options if snow needs to be periodically cleared from the array. Top-of-pole arrays can also be used with tracker systems to help boost PV production even more (see "Tracker Types & Features" sidebar).

Because the array sits several feet from the ground, allowing for the greatest amount of airflow, top-of-pole mounted arrays operate at lower temperatures than roof- and ground-mounted arrays. This reduces the amount of power lost when ambient temperatures are high.

Top-of-pole mounts generally are not viable options in urban or suburban areas due to the yard space required. And the additional excavation required to place a pole and trench to the electrical distribution can make top-of-pole mounts more costly in certain situations. Finally, side-of-pole mounts, which are popular for small stand-alone outdoor lighting systems, are also available.

Commercial Racking Systems

The proliferation of commercial PV systems has resulted in the advent of a number of different racking approaches for large arrays and installations on flat roofs. These solutions include custom designed and fabricated mounting structures, integrating the PV array into the roofing material, and using a nonpenetrating ballast system for flat-roof applications.

The most common type of commercial racking system is the ballast rack, which uses the weight of the modules and rack in conjunction with ballast to securely keep the arrays in place. Masonry blocks are placed in ballast pans that are located either directly under, or in front of and behind,

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Ballast mounts rely on the weight of the ballast, modules, and racking—rather than fasteners and roof penetrations—to secure the array.

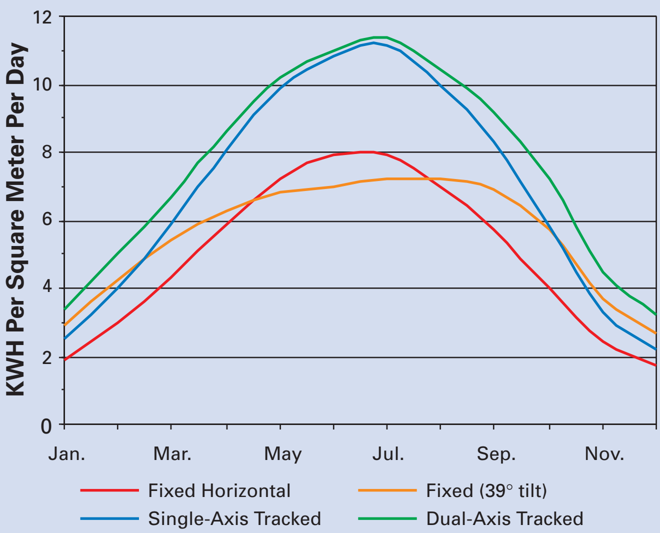
Courtesy www.power-fab.com

Tracker Types & Features

The sun's path through the sky changes throughout the day: In the morning, it's low on the eastern horizon; at noon, it's high in the sky; and at sunset, it's low again, but on the western horizon. Because a PV array generates the most energy when its modules are directly facing the sun, those interested in getting every last watt-hour from their PV modules often investigate tracking systems.

Trackers are available for almost all sizes of PV arrays. For smaller residential applications, tracking systems are commonly mounted on top of an appropriately sized steel pole. Larger commercial systems will often employ long rows of PV modules set on single-axis trackers.

Fixed vs. Tracked Arrays



Courtesy NREL and Array Technologies

A good site for a tracked array receives dawn-to-dusk sun. There's no point in buying a tracker if your site doesn't begin receiving sunlight until 10 in the morning, or loses it at 2 in the afternoon due to shading from hillsides, trees, or buildings. When located at a site with a wide-open solar window, a tracked array will generate approximately 25% to 40% more energy annually than a static array.

There are two forms of PV tracking: single axis and dual axis. The single-axis method follows the sun's path from east to west, with the array tilted at a fixed or manually adjustable angle off the horizon. This approach is common in large-scale, commercial installations but can be used in residential applications as well.

Dual-axis trackers adjust the PV array to track the sun's path from east to west and adjust the array's tilt to account for the change in the sun's altitude.

Trackers come in two basic types: electrically operated and thermally operated (referred to as "active" and "passive"). Common electrically operated trackers for residential systems typically rely on photosensors that signal motors (via a controller) to orient the array toward the sun as its position changes throughout the day. Thermally operated trackers use the transfer of mass (weight) to follow the sun. In a passive system, a canister and shading fin is attached to the east and west sides of the tracker. These tubes are filled with a material—usually Freon—that vaporizes (becomes a gas) at relatively low temperatures. As the sun hits one canister, the warmed Freon vaporizes and pushes some of the cooler liquid Freon to the other side. This process transfers weight from the one side of the tracker to the other and orients the array toward the sun.

Both electrical and thermal trackers have associated advantages and disadvantages. The big advantage of electrical trackers is that they are extremely precise and will generate more energy for a given period than passive trackers. But electrical trackers are not without their weak points. Because they rely on electronics and electric motors, their reliability is lower than thermally operated trackers. Electrical trackers are also sensitive to damage from lightning. The manufacturers of these trackers have made great strides in making their products resistant to lightning damage, but in the event of a close or direct strike, damage still may occur.

Due to their simplicity, thermal trackers have proven to be very durable in the field. On the downside, because they rely on solar heat, these trackers can be slow to respond. At night, they remain facing west and rely on early morning sunlight to return to the east. This process may take an hour or more depending on ambient temperature. In winter weather, thermal trackers can be somewhat sluggish and imprecise in performance because they are dependent on building up enough heat to vaporize the Freon.

Whether a tracker will be cost effective for your application will depend in part on your seasonal electrical use patterns. Trackers give you more gain in the summer when the days are longer, with somewhat less improvement in the winter. For grid-tied systems with annual net metering, this can be a bonus because the tracker's excess summer production will help offset your winter utility bill. In PV-direct (batteryless) water-pumping systems, trackers with as few as two PV modules can be cost-effective compared to buying additional modules to pump the amount of water required.

Array Technologies' Wattsun active tracker.

Wattsun tracker gimble and drive system.

Courtesy www.wattsun.com (2)

The Zomeworks passive tracker functions by thermal phase change.

Courtesy www.zomeworks.com

the PV array. These racks can add a significant roof load, up to 30 pounds per square foot, depending on the array engineering requirements. In an effort to minimize roof loading, there are also mounting systems that use ballast in conjunction with roof attachments to help minimize both roof penetrations and excessive loading on the roof structure. Ballast racks are available from manufacturers in both fixed and adjustable tilts. The low fixed-tilt-angle models (5 to 10 degrees) generally require less ballast and can be used in higher wind-speed areas than the taller, adjustable racks.

Access

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Mount Manufacturers:

Conergy • www.conergy.us • Top-down rail

Direct Power & Water • www.directpower.com • Top-down rail, top-of-pole, rack & ballasted

General Specialties • 208-265-5244 • Top-of-pole

Lorentz • www.lorentz.de • Active trackers

PVee • www.pvee.net • Active trackers; custom rack & ballasted for commercial applications

ProSolar • www.prosolar.com • Top-down rail

Schuco • www.schuco-usa.com • Top-down rail

Sharp • www.sharpsolaritson.com • Top-down rail kit

Solar Racks • 707-826-9214 • Rack

Sun Earth • www.sunearthinc.com • Top-down rail

SunPower • www.sunpowercorp.com • Top-down rail kit, commercial ballasts, & trackers

UniRac • www.unirac.com • Top-down rail, rack, ballasted, & custom commercial

Wattsun • www.wattsun.com • Active trackers

Zomeworks • www.zomeworks.com • Passive trackers, rack & top-of-pole