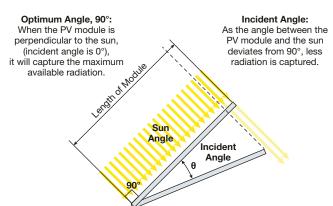


This passive tracker uses the sun—and a liquid that condenses into a gas when heated—to position the modules instead of motors, gears, or electronics.

n the northern hemisphere, a fixed PV array is usually oriented south (180° azimuth), to capture as much sunshine as it can. But that results in less-than-optimal energy production because the PV modules' surfaces face the sun directly for only a short period each day (at solar noon). Additionally, because the sun is higher or lower in the sky each day depending upon the time of the year, tilt adjustments are necessary to optimize seasonal production.

The sun's intensity is at its maximum on a PV module when it is striking it perpendicularly—the incident angle is 0°. The larger the incident angle, the smaller amount of energy that hits the module. When the incident angle increases, reflection also increases and the amount of energy that can be gathered drops.

Insolation as a Function of Incident Angle



To maximize production, tracking systems keep PV modules facing the sun all day throughout the year. Trackers can be single- or dual-axis, and either passive or active. A single-axis tracker follows the daily movements of the sun from east to west (about 15° per hour). A dual-axis tracker also adjusts the array's zenith, changing its tilt to keep the modules truly perpendicular to the sun's rays all year long.

Passive tracking relies on the sun to heat a liquid in canisters affixed to the sides of the array. As the liquid in the unshaded canister heats up, it expands into a gas, which pushes the heavier liquid to the shaded canister, shifting the weight to that side of the array, which causes it to rotate. Zomeworks (zomeworks.com) pioneered the passive PV tracker.

Active tracking relies on hardware or software that tracks the sun's movements. Wattsun (wattsun.com) solar trackers use motors and gears activated by onboard photosensors that find the brightest spot in the sky. DH Solar (dhsolar. net) uses software to calculate the sun's track based on latitude, longitude, date, and time. Motors and gears still do the heavy work. Bob-O Schultze of Electron Connection says that "passive trackers point west each night and sleep in late, especially on winter mornings." Schultze has five active PV trackers at his home/office near the California-Oregon border.

Tracking increases production throughout the year. The amount of gain varies depending on the latitude, amount of unobstructed horizon, and local weather. Dual-axis trackers can provide up to 40% increased energy harvest compared to fixed arrays.

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dollars & sense

renewable energy in the spotlight



This active tracker is pointed at the brightest spot in the sky, even though there is no direct sunlight yet. The bright spot is quite low on the horizon—hence the array's nearly perpendicular position to the ground.

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The downside of tracking is the higher cost of the tracker, plus the costs of concrete, labor, and burly structural components needed for the pole-mounted array. With active trackers, there's the potential for failure of motorized and electric components. Repairs and maintenance costs can offset any production gains, as can storm damage, which is more likely with a tracked system. While inverters and PV modules carry 10- and 25-year warranties, respectively, most tracker warranties range from two to 10 years.

When PV modules were more expensive, trackers were used to squeeze more energy production out of the modules. Now that modules are much less expensive, trackers may not make sense for some applications. You'll need to compare the cost and maintenance of tracker hardware to the cost of adding more modules to a fixed array to achieve the same energy output.

For commercial PV installations with an economy of scale that residential PV doesn't have, tracking often comes out ahead—especially single-axis. For grid-tied residential PV systems, the best choice is usually a fixed array. With inexpensive PV modules, the most cost-effective approach—assuming enough available space—is to install more modules.

For an additional cost, a rack system could be used that allows for seasonal tilt adjustment instead of tracking. According to the National Renewable Energy Laboratory's *Solar Radiation Data Manual*, changing the tilt angle of a fixed array four times (midway between the solstices and the equinoxes) per year can result in up to a 5% annual increase in energy production—but only at higher U.S. latitudes.

Both aesthetic and practical considerations can come into play. Modules mounted parallel to the roof can have somewhat less production than ones more optimally tilted toward the sun, but they are less aesthetically obtrusive. Then there is the matter of climbing on the roof several times a year to adjust the array's tilt. "Many folks with utility-tied batteryless systems request a seasonal adjustable rack," says David Duffield of DP&W Solar, a PV rack manufacturer, "but then they never change the angle—that's just human nature." Tilting the modules away from the roof plane also creates higher wind loading on the array, and the increased stress on the attachment points and the building needs to be taken into account.

If your PV system is off the grid, other considerations apply. Duffield, who lives off-grid, notes the benefits of adjusting the panels for increased winter production. When the number of daylight hours is shortest, more captured solar energy mean less use of the backup generator. The steeper winter angle also means less snow buildup on the modules.

"It's not the slam-dunk it was 10 years ago," says Michael Reed of Array Technologies, which makes both residential (Wattsun) and commercial PV trackers. Wattsun has sought to revive residential PV tracking by offering less expensive single-axis tracking. East-west tracking provides a larger increment in energy production than tracking the sun's annual changes in height. Downscaling from dual- to single-axis tracking reduces the tracking cost by about half while still providing a 30% increase in production over a fixed array.

—Andy Kerr