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Rutgers Agrivoltaics Program
New Jersey Agricultural Experiment Station

# Impact of Azimuth Angle on Energy Production of an Agrivoltaic Array

This information sheet addresses solar array layout flexibility as it might impact energy production and farming for agrivoltaic or dual-use arrays in the Northeast. Single-axis-trackers (SATs) have reached a high level of mass-production cost-reduction and now dominate the market for installation in large utility-scale solar power plants. Recent data shows more than 90% of large arrays are being built with SATs[1]. Driven by the desire to maximize the annual energy output, trackers are usually installed with their azimuth or axis of rotation aligned North-South. During the day, each row will rotate toward the East to capture the morning sun and rotate toward the West in the afternoon to capture the afternoon sun. Generally, the control algorithms also aim to prevent inter-row shading effects, so during the early morning and late afternoon the tracking is typically modified (a.k.a. back-tracking) so that the rotation angle is reduced to prevent inter-row shading.

Farming on the other hand has different constraints such as the geometry of the parcel or the terrain contours that might impact water drainage. Therefore, farmers frequently adopt plowing or tilling directions that are not aligned true North-South. Thus, when farmers and solar developers work together planning agrivoltaic projects there should be room for compromise to achieve excellent energy production while also maintaining excellent farming productivity.

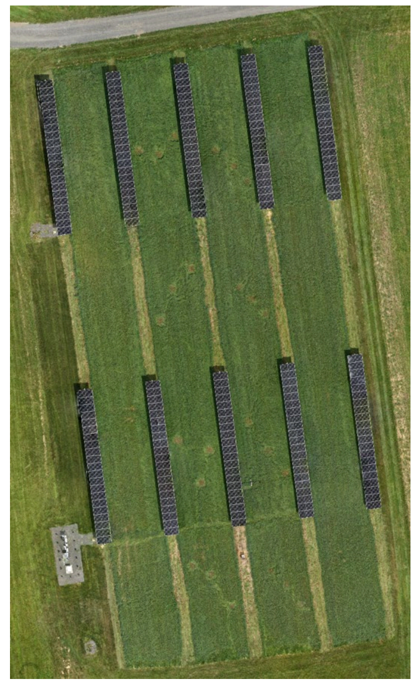

Figure 1: Rutgers University Snyder Farm with a single-axis tracker array installed with an intentional -7° azimuth adjustment and 32 feet row spacing.
Image © Rutgers Agrivoltaics Program.

One example of such an agrivoltaic array design compromise can be seen in Figure 1 showing the SAT array at Rutgers University's Snyder Farm that was installed with a slight negative (counterclockwise) 7° twist (i.e., azimuth angle = 173°, with 180° being the reference value for true N-S alignment) to better align with the plot's prior farming use and to fit with other adjacent fields without wasting space. This array has 10 rows each having 21 modules in single-portrait (1P) orientation, with two control areas to the South of each block of 5 rows. Two other compromises aiming for better agricultural usage were also included: 1) the pivot point of the trackers was raised to 8' above the ground, higher than might normally be chosen for a non-agrivoltaic tracking array, and 2) the row spacing was set at 32', wider than might normally be used (yielding a ground coverage ratio, GCR, of 0.215[2]).

Energy production predictions for solar arrays can be performed by a variety of software packages. The National Renewable Energy Lab (NREL) offers PVWATTS[3] and SAM[4], which are both free and offer different levels of complexity and potential accuracy. Commercial software, such as PVSyst[5] or PVCase[6], are also available. All of these calculation tools integrate typical sunlight variability and seasonality to deliver projections of annual energy yield that can be factored into any project's financial bottom line. For the discussion presented in this information sheet, PVWATTS was used with the coordinates for the Rutgers University Snyder Farm in Pittstown, NJ (40.56° N, 74.96° W). Similar results are expected for other locations in New Jersey and for other solar modeling software.

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[1] https://emp.lbl.gov/publications/utility-scale-solar-2024-edition

[2] For this work, the GCR is defined by the module dimension perpendicular to the rows divided by the inter-row spacing or pitch. The ZnShine 450W modules in the Snyder Farm array have a height of 2.094 meters (6.87 feet): 6.87/32 = 0.215.

[3] https://pvwatts.nrel.gov/pvwatts.php

[4] System Advisor Model, https://sam.nrel.gov/

[5] https://www.pvsyst.com/en/

[6] https://pvcase.com/

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**Array Azimuth Adjustment**

As shown for the Snyder Farm installation above, azimuth adjustments may be helpful for building an agrivoltaic array that allows for efficient farming operation on the site. The energy impact of azimuth adjustment was tested for a wide range of azimuth values using the Snyder array's detailed specifications. Modeling was done in PVWATTS using premium bifacial modules, the back-tracking algorithm, and specifying a ground-coverage-ratio (GCR) of 0.215, all matching the Snyder Farm array as closely as possible. With zero deviation from the North-South alignment, the annual energy production was predicted to be 1,566 $kWh_{AC}/kW_{DC}$. The prediction corresponding to the as-built -7° rotation yielded 1,564 $kWh_{AC}/kW_{DC}$. Data for a wide range of other azimuth angles were calculated and normalized by the zero rotation number to determine a relative energy production percentage compared to an ideal installation with true North-South rows.

Figure 2 presents the predicted normalized annual array output as a function of the azimuth angle (deviation from true North-South orientation). The energy reduction impact is less than 2% for azimuth angles ranging from -30 to +30 degrees, and for azimuth angles ranging from -20 to +20 degrees the energy reduction is predicted to be 1% or less. For the actual counterclockwise 7° azimuth adjustment at Snyder Farm, the fractional annual energy reduction is less than 0.2%. Positive azimuth adjustments correspond to rows aligned on a diagonal running NE-to-SW, while negative azimuth adjustments correspond to rows aligned on the opposite diagonal, running NW-to-SE. Note that there is slight asymmetry to the curve shown in Figure 2 due to real differences in morning and afternoon sunlight conditions typical for New Jersey, slightly favoring a positive azimuth adjustment.

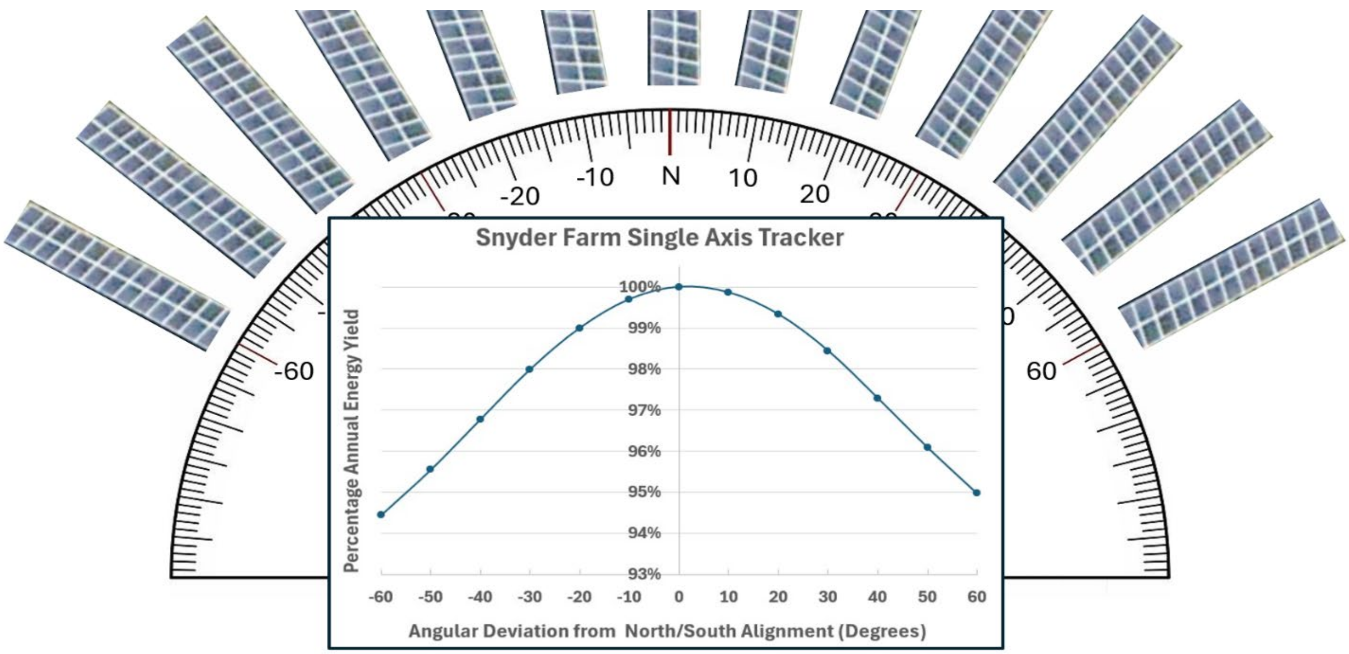


Figure 2. Predicted relative annual energy production yield at Rutgers University Snyder Farm as a function of azimuth adjustment. Protractor and single rows are drawn to emphasize the range of deviations from the North-South orientation represented in the graph.

Changing the azimuth angle of a solar array installation may also have other project financial implications depending on terrain contours, soil types, shading by nearby foliage, etc. For projects that are planning to sell electricity into the wholesale market, it is likely that the time-varying value of electricity should also be factored into the calculation. This effect has been analyzed for fixed-tilt arrays[7] showing that the wholesale revenue can be increased by azimuth adjustments that point the array more toward the West thereby

[7] P.R. Brown and F.M. O'Sullivan (2019), "Shaping photovoltaic array output to align with changing wholesale electricity price profiles" *Applied Energy* **256** https://doi.org/10.1016/j.apenergy.2019.113734

enhancing generation in the afternoon when the electricity is more valuable. This could suggest a preference for negative azimuth changes.

**Additional Comments**

As noted above, solar developers and farmers should work collaboratively to optimize array layout for combined energy and farming efficiency. In addition to energy output (trackers provide a significant boost compared to fixed-tilt installations), there are several farming impacts that should be simultaneously considered, including:

1. **Land "fit"**: The array should fill the land evenly without lopping off oddly shaped corners that will end up being difficult to farm. This also includes the need for end-of-row turnaround space for farming equipment that would be operating between the rows.
2. **Shading uniformity**: Trackers provide a good level of uniformity of the light that reaches the ground for agricultural use. Tracker rows create direct-light shadows that move laterally, West to East, and, on average, provide good cumulative light exposure everywhere. Trackers that are close to the ground have less uniform shading while those raised intentionally higher (perhaps also to ease equipment operation underneath) have more uniform illumination. The shading pattern changes gradually with changes in azimuth angle, though the effects aren't very dramatic until large azimuth angles are imposed[8].
3. **Crop rotation**: Soil health considerations often drive farmers to rotate crops year after year. This would then require that the agrivoltaic array should be compatible with the various crops that might be chosen for such crop rotations.
4. **Topography**: Land parcels can have significant topographical variation. This can impact both the solar energy production as well as cropping. Steeper grades may experience more erosion and farmers may choose to till across the grade to reduce this effect. As a further complication, the addition of a solar array will add "drip lines" where rain falling on the modules will drain at the lower edge and perhaps amplify erosion at ground level[9]. Farmer measures and efforts to prevent erosion should be factored into an agrivoltaic array design.
5. **Key crop operations**: Farming requires the use of various equipment such as for sowing, irrigation, fertilization, harvesting, pest and weed control, and other operations. The key question is "How will the presence of a solar array impact each of these operations?". Also, can the array accommodate the various operations by short-term changes in tracking angle or other modification? Farmer input is critical to make sure the array does not negatively impact farming operations.

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Additional agrivoltaics information can be found at: https://agrivoltaics.rutgers.edu



[8] W.R. Rucker and D. P. Birnie, III (in preparation), "Shading and energy impacts for farmer-friendly agrivoltaic arrays". This work covers all array types and a wider range of geographic locations. This work was also presented as a poster at the 2024 Agrivoltaics World Conference in Denver Colorado. This poster is archived here: (https://agrivoltaics.rutgers.edu/wp-content/uploads/2025/11/Shading-and-Energy-Impacts-for-Farmer-Friendly-Agrivoltaics-Array-Installation_poster.pdf)

[9] Li et al. (2025), "Ecological impact of rain splash erosion on saline-alkali grassland surfaces under photovoltaic panels" *Catena* **254** https://doi.org/10.1016/j.catena.2025.108988