New Tilting Nearly-Vertical Bifacial Solar Arrays for Enhanced Agrivoltaics

MSE Materials Science & Engineering

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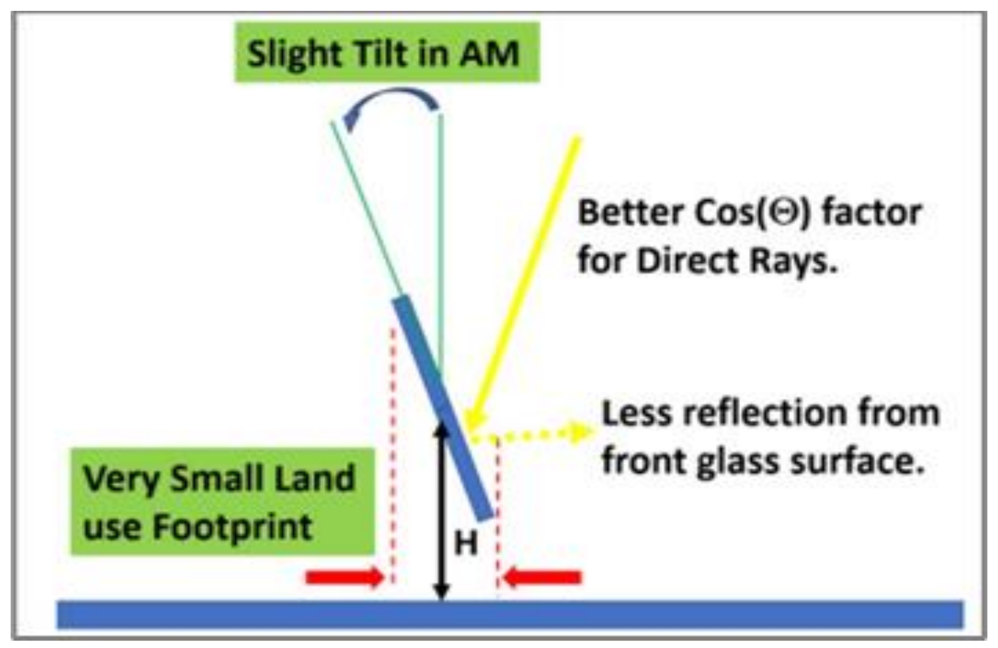
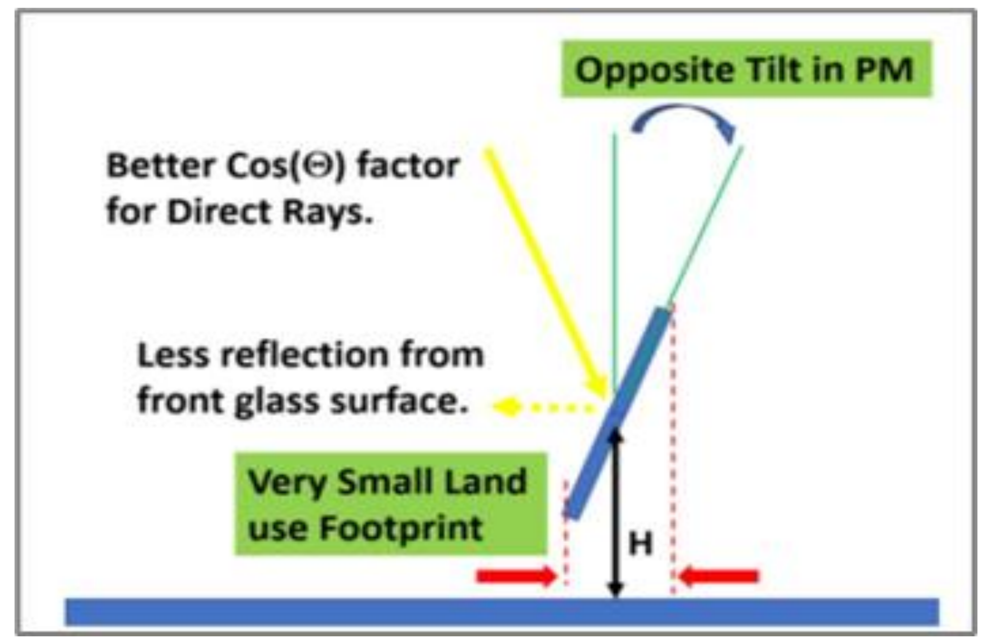
Introduction

A new solar array design is being investigated that combines the benefits of single axis tracking arrays and vertical bifacial arrays with the goal of enhancing the energy production of agrivoltaic solar arrays while maintaining ample room for crop growth. This array design is referred to as Tilting Nearly-Vertical Bifacial (TNVBF) and involves small-angle tilting of a vertical bifacial panel to improve sun incidence angles in the morning and afternoon to increase efficiency while the sun is at its height.





Background

Increasing the amount of power generated by renewable sources such as solar has become a priority as the world seeks to combat climate change and decrease fossil fuel usage. Since 2000, solar energy generation in the U.S. alone has grown from less than 1 GWh to over 100 GWh [1], and according to the International Renewable Energy Agency (IRENA) approximately 1000 GW of renewable power needs to be added each year worldwide to maintain global warming below 1.5 °C [2]. With this trend of increasing solar power generation and the necessity of even greater expansion of renewable energies to reach climate goals comes an issue regarding land-use. Conventional solar arrays take up sole use of the land that they are installed on, preventing other beneficial activities that could make use of the land such as farming. The solution to this issue is known as agrivoltaics, the dual-use of land for both solar power generation and agriculture. Solar arrays designed for agrivoltaic applications differ slightly from conventional array designs because agrivoltaic arrays must be designed around the requirements of farming operations, such as the size of machinery needed for harvesting.

Currently, the majority of agrivoltaic arrays are single-axis tracking designs, which rotate from East to West to track the location of the sun as it moves throughout the day to maximize energy capture. Single axis-tracking arrays can either be installed at a height far above the crops to allow machinery to pass underneath or at ground-level with greater spacing between the rows. However, raised tracking arrays are difficult to install, maintain, and clean and ground-level tracking arrays take up a large amount of space and may create significant shading on the crops. More recently, vertical bifacial arrays have emerged as an option for agrivoltaics. These vertical bifacial arrays are able to make efficient use of sunlight during the morning and evening hours while allowing crops to benefit from full sunlight conditions while the sun is at its peak. However, they suffer a loss in efficiency due to large row spacings and inability to make effective use of the brightest periods of sunlight at midday. The solution to these issues would be an agrivoltaic array design that combines the principles of both existing designs to find a balance between energy efficiency, simplicity, and space taken up by the array.

A single-axis tracking array raised above crops. Image from Optimum Tracker.

A single-axis tracking array at ground level. Image from Advanced Solar Products.

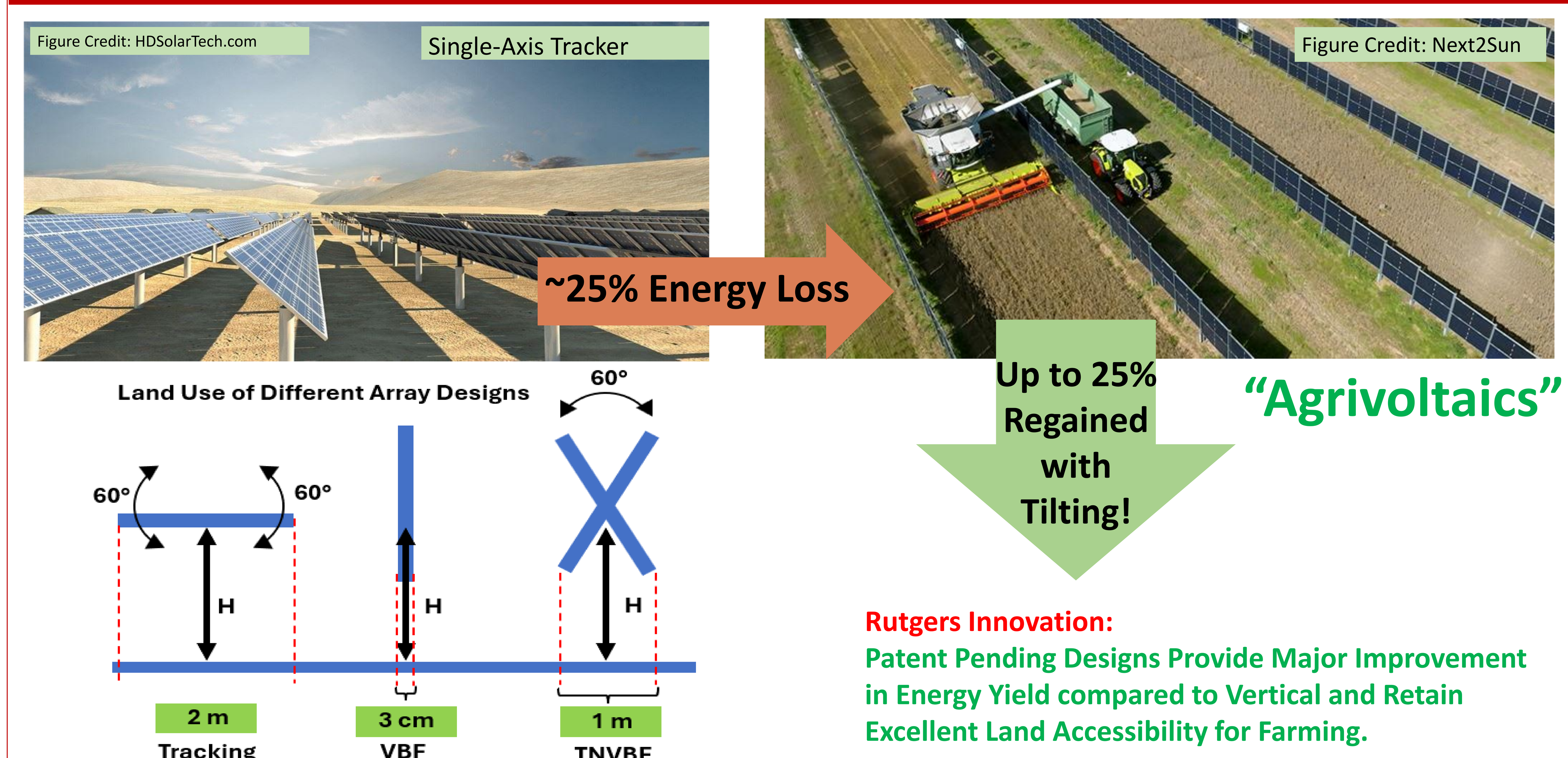
A vertical bifacial array. Image from Rutgers Agrivoltaics Program.

Methods

The ground-mounted tracking array installed at Snyder Farms and the vertical bifacial array installed at Rutgers Animal Farm, both products of the Rutgers Agrivoltaics Program, were used for this comparison. PVWatts data on expected monthly energy output for each array was compiled and divided by the number of days in each month to give an estimate of daily energy output. A cosine function was then fitted to these daily energy values through a least-squares regression for both arrays in order to model the energy output across the full year. These fits were then validated against the existing partial-year experimental energy data that has been collected from the arrays since their installation. This provided a comparison between the energy output of a tracking array and a vertical bifacial array to understand the losses inherent to the vertical orientation.

To estimate the energy increase from vertical bifacial to TNVBF, Typical Meteorological Year data on sun position and irradiance taken every hour was obtained from the National Solar Radiation Database (NSRDB) for New Brunswick, New Jersey [3]. Normal vectors to each of the three array types were established in a Cartesian coordinate system with the x-coordinate corresponding to East-West, the y-coordinate corresponding to North-South, and the z-coordinate corresponding to up-down. The TNVBF array was chosen to have a tilt angle of 30° from sunrise until noon and a tilt angle of -30° from noon until sunset. The angle between the sun and the panel normal was calculated from the dot product of the sun vector and the panel normal vector. This angle was then multiplied by the Direct Normal Irradiance for each hour, and these results were summed to get the total energy available from direct irradiance for each array type. The solar module dimensions used to illustrate ground coverage of the three array types are for a ZNshinesolar ZXM6-NHLDD144 Series Bifacial Panel.

Results



Conclusions

TNVBF solar arrays combine the design principles of single-axis tracking arrays and vertical bifacial arrays, creating a result that outperforms vertical bifacial arrays while maintaining the benefits of minimal impact on crops placed between the panel rows and ease of maintenance and cleaning. This positions TNVBF arrays as a promising new array design that can be incorporated into future agrivoltaics projects.

References

[1] International Renewable Energy Agency. (2023). *World Energy Transitions Outlook 2023.* https://www.irena.org/Publications/2023/Jun/WorldEnergy-Transitions-Outlook-2023.

[2] U.S. Energy Information Administration. (2024). *October 2024 Monthly Energy Review.* https://www.eia.gov/totalenergy/data/monthly./pdf/mer.pdf

[3] NSRDB. https://nsrdb.nrel.gov/.

Acknowledgements

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