What Role do Vertical Bifacial Solar Panels Play in the Future of the Solar Industry?

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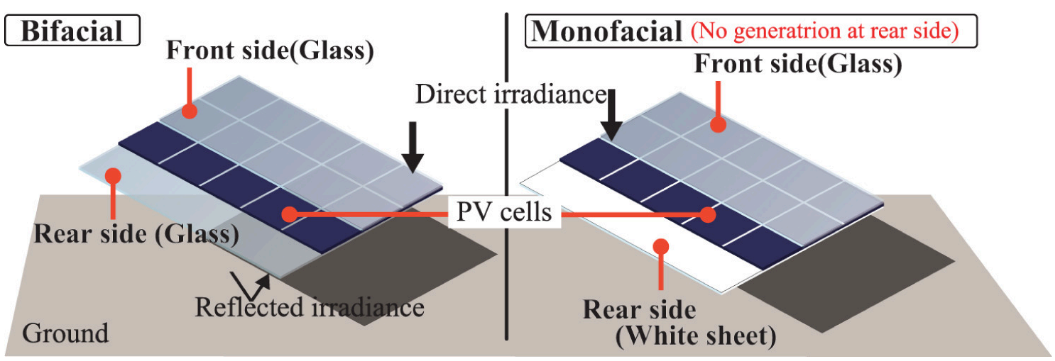
Introduction

Vertical bifacial solar panels are an emerging photovoltaic (PV) configuration gaining traction as they can address several of the challenges associated with traditional monofacial PV panels. Unlike traditional solar panels that generally face south (in the northern hemisphere) and have a peak output when the sun is directly overhead, vertical bifacial solar panels are oriented east and west to capture peak output as the sun rises and sets. Vertical bifacial solar panels are still not widely deployed, but bifacial solar panels are becoming more popular in the solar industry to capture diffuse light and improve efficiency. To maximize solar output, it generally requires bifacial panels in tandem with tracking technology — increasing energy production by up to 40% compared to fixed monofacial solar systems. While bifacial solar panels are driving improved energy output, they are not addressing larger issues like the heat island effect, energy loss from heat, general panel degradation, land use, and the disconnect between peak production and demand times. Vertical bifacial solar panels are primed to alleviate some of these issues since production aligns more closely with peak energy demand times and their vertical orientation helps to limit heat impacts to panels (i.e. degradation and efficiency loss). Vertically integrated bifacial solar panels also can make more efficient use of space as fences or in line with rows of crops to provide partial shading. Some methods are even adding reflectors on the ground to capture more solar energy when the sun is overhead, contributing to a higher ground albedo that can lower localized temperatures. Ultimately, vertical bifacial solar panels face an uphill climb as most utility-scale solar farms continue to utilize the typical tilted orientation towards the south, but if they can prove economic feasibility and improved efficiency, vertical solar farms with bifacial panels will likely be an important part of industry's future.



(Figure 1. Differences between bifacial and mono-facial PV modules.)[1]

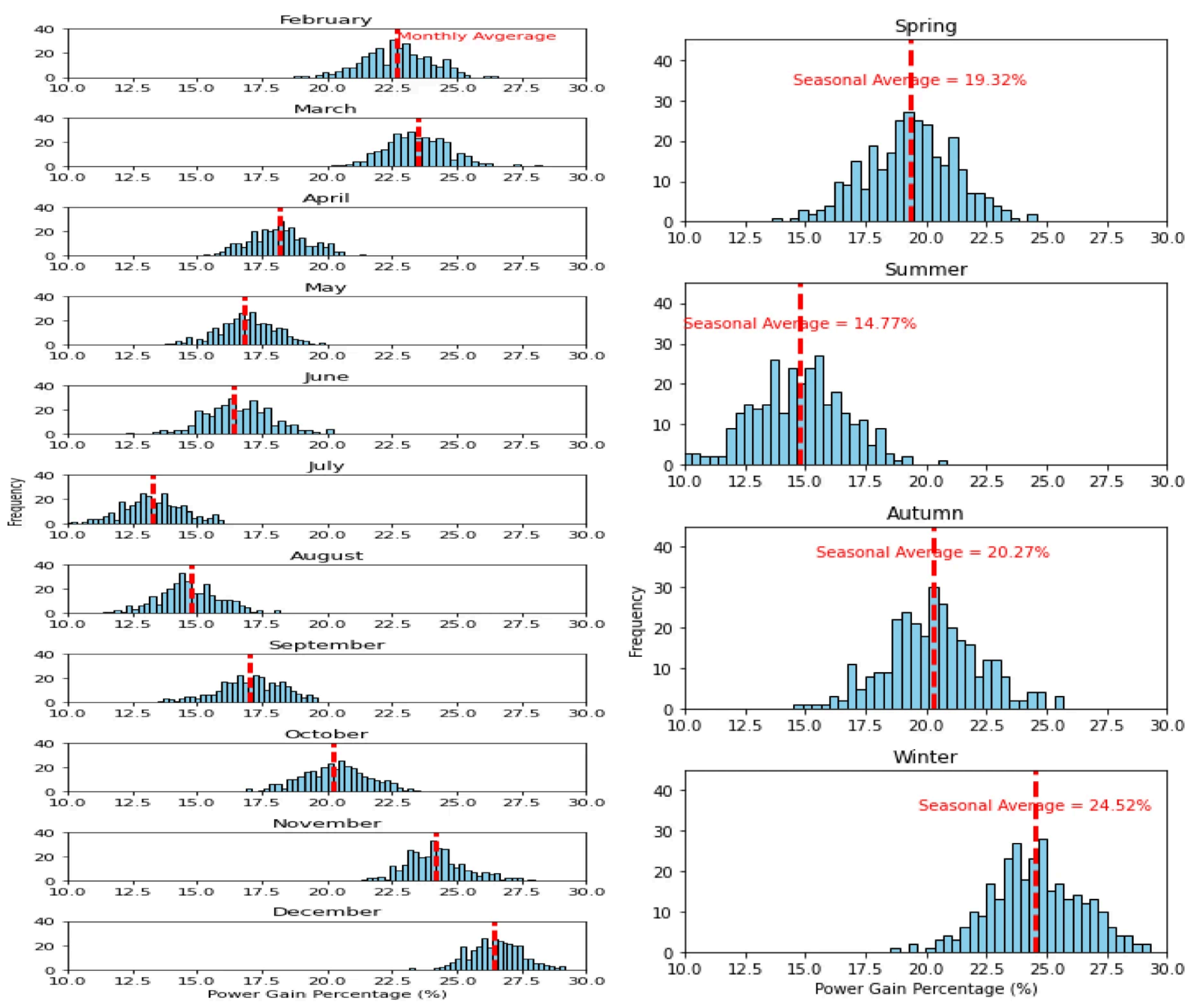
Energy Output and Efficiency

One of the most compelling features of vertical bifacial panels is their unique power output profile. Because of their east-west orientation, they produce two daily power peaks — one in the

[1] Optimal design of bifacial PV system to mitigate duck-curve problem of power system with the UC problem

morning from the east and one in the late afternoon from the west. This energy output aligns more closely with typical electricity demand patterns, with people using the most energy in the mornings and afternoons before and after work. This double-peak generation can help to alleviate strain on the grid and provide clean power more consistently during high-demand periods. Research done in Germany demonstrates that with vertical bifacial solar panels integrated into the grid, it could significantly reduce the production needed from natural gas peaker plants or energy storage.[2]

Besides better timing of production, vertical bifacial solar panels can achieve better annual energy yields than traditional tilted monofacial panel orientations. With favorable conditions, especially in snowy winter months, vertical bifacial solar panels can boost power gain percentage by nearly 25% compared to tilted monofacial panels.



(a) (b)

2 Integration of vertical solar power plants into a future German energy system

(Figure 2. VBPV compared to TMPV. (a) Monthly power gain (Percentage, %) for VBPV over TMPV. (b) Seasonal variations in power gain (Percentage, %) for VBPV over TMPV. The histograms represent the frequency distribution of the power gain percentages, and the red dashed lines indicate the seasonal average power gains.)[3]

During snowy winter months, increased albedo contributes to higher performance for vertical bifacial solar panels since they are able to capture more diffuse and reflected light. Vertical panels also don't need snow cleaned off in the winter months and face less of a risk of hail damage. In addition to these benefits in the winter, vertical panels in the hot summer months run cooler than their tilted counterparts — leading to increased efficiency. Other ways to improve vertical panel efficiency are to "sculpt" the ground into triangles around the panels and increase albedo using reflectors. One study found that this method boosted annual energy output by 50% compared to monofacial panels.[4]

While vertical panels alleviate several issues with typical tilted panels, there still are some energy output drawbacks. For instance, a UK analysis found that monofacial vertical panels can yield 20-30% less annual energy than optimally tilted south-facing panels. The major losses occur in the summer months when the sun is high so the vertical panels are not receiving optimal power for more hours during the day.[5] Still, vertical panels in northern regional climates take advantage of increased output in winter months, which can partly compensate for the more dismal summer months.

This UK study did not look at bifacial solar panels, but the dual-sided panels are crucial to optimize vertical orientations. Another study comparing tilted bifacial panels and vertical bifacial panels found the vertical orientation could retain 82% of the tilted installation energy yield — with some months reaching an energy yield of up to 100%. The study also mentions that though vertical panels produce a lower energy output, they provide unique advantages to potentially alleviate peak load issues on the electrical grid, require less cleaning maintenance, and take up less space.[6] Vertical bifacial solar panels do offer an alluring set of benefits compared to tilted panels, yet they are not the end all be all for the solar industry. Likely, a combination of different panel orientations would be optimal to maximize solar output.

Dual-Purpose Applications

Outside of their energy output advantages (i.e. matching peak demand times), vertical bifacial solar panels can be utilized in a myriad of applications like fencing and agriculture — thus

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[3] Comprehensive study on the efficiency of vertical bifacial photovoltaic systems: a UK case study
[4] Ground sculpting to enhance vertical bifacial solar farm output
[5] https://www.eerenewables.co.uk/solar-guides/horizontal-vs-vertical-solar-panel-installation/
[6] Evaluating the real-world performance of vertically installed bifacial photovoltaic panels in residential settings: empirical findings and implications

expanding solar use cases within sustainable land practices. One of the most intriguing aspects of vertical solar is its potential use in agriculture, whether that be as fences or in line with rows of crops. Agriculture is an exciting application for vertical solar panels as it allows land to serve a dual-purpose. A major drawback for traditional solar panels at utility-scale is that they take up large areas of land. An agrivoltaics-focused company out of Germany states that vertical panels built in parallel with crops still allows for up to 95% of land use for agriculture whereas traditional tilted panels would only allow for around 30% of land use.[7] The implications for deploying vertical solar panels in conjunction with agriculture would be huge, bolstering utilization while saving on land usage.

Despite their inherent reduction in energy production compared to optimally tilted panels, vertical panels offer advantageous properties like antisoiling and strong weather-resilience — making them ideal for use as fences or along highways as barriers. Traditionally tilted panels are susceptible to energy loss from dust accumulation, snow coverage, and hail damage. Vertical panels are less susceptible and require less maintenance, therefore making them optimal for non-traditional use. Balconies, fences, and even highway barriers are potential avenues for vertical solar panel implementation as these could serve mutually beneficial purposes.

Several interesting challenges arise for vertical solar panels used as fences or on farms in terms of permitting and public perception. Depending on the scale of the project or the location, vertical solar adoption could face headwinds from local backlash or complex permitting processes. In some cases, farms retrofitted with solar can lose their agricultural classification — leading to higher taxes and loss of farm-specific tax incentives.[8] This complexity in zoning and permitting laws hinders the adoption of agrivoltaics, and will slow overall growth unless policies shift.

<u>Economic Considerations</u>

Bifacial PV panels do boost energy output and efficiency, yet they come at a premium cost compared to monofacial panels. For smaller solar systems, monofacial panels might still make more economic sense as the true benefits of bifacial panels come from larger outputs. However, bifacial panels can decrease levelized cost of energy (LCOE) as they are producing more energy over time. Even with their higher costs at around $0.40-$0.55 per watt (10-20% more than monofacial panels), bifacial panels produce 10-30% more energy depending on conditions like orientation and albedo. One energy study found that their return on investment for a 500kW system under the right conditions can have a shorter payback period and significantly higher lifetime value.[9]

[7] Vertical Agri-PV: Maximum degrees of freedom for agriculture
[8] Emerging technology allows solar panels and agriculture to coexist, legal hurdles remain
[9] Bifacial Solar Panels: Are They Worth It for Your Commercial Project?

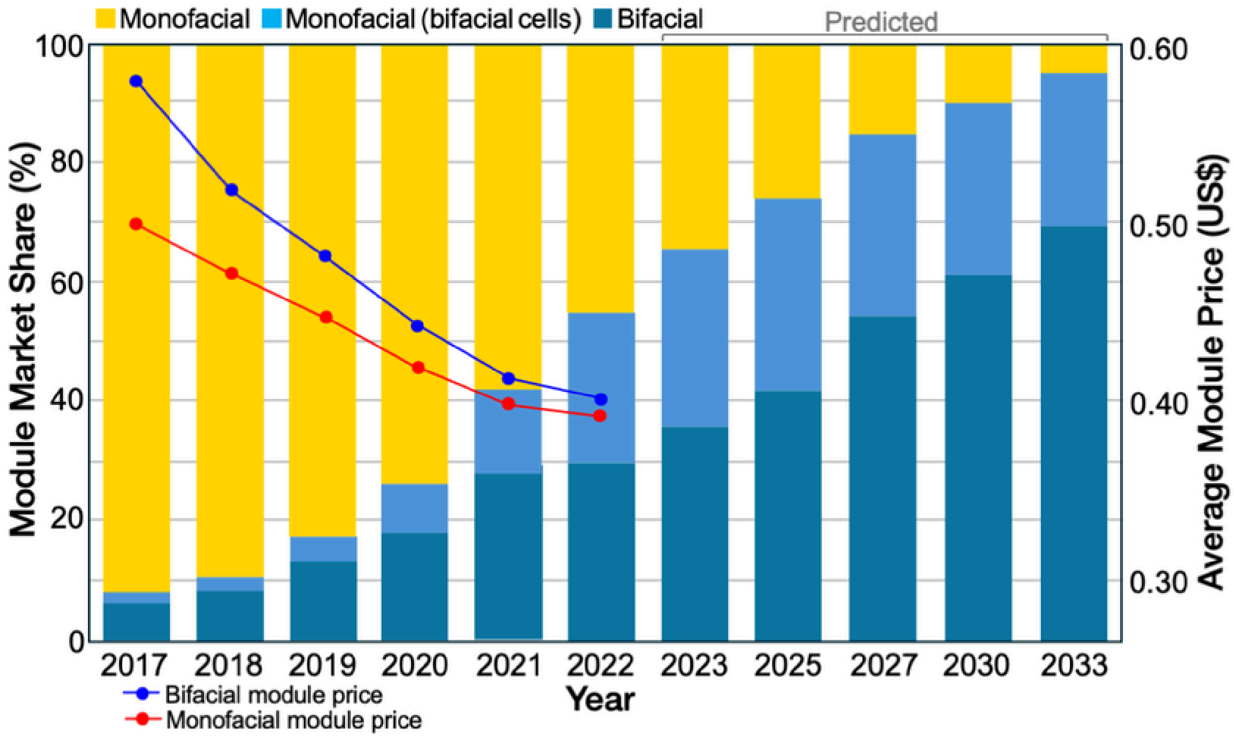
500 kW System	Monofacial	Bifacial
System Cost	$650,000	$715,000
Annual Output	750,000 kWh	900,000 kWh
Annual Savings (@$0.12/kWh)	$90,000	$108,000
5-Year Tax Benefit (ITC, MACRS)	$200,000	$220,000
Payback Period	7.2 years	6.4 years
25-Year Savings	$1.75M	$2.15M

Another cost study looks specifically at how optimally tilted bifacial panels compared to monofacial panels can reduce LCOE by up to 8%. The degree of the tilt depends on several factors globally including albedo and land costs.[10] Though this study does not look at vertical panels directly, it proves the efficacy of bifacial panels and the various orientations that can lower solar LCOE in different parts of the world. Tilted bifacial panels still produce the highest energy output annually, yet there still is value to vertical configurations as they can optimize for land use, agriculture co-location, and their two daily energy peaks more closely match high energy demand times.

Industry Outlook

Monofacial panels still dominate the solar market worldwide as bifacial panels are relatively early stage and more expensive. However, bifacial panels are set to see substantial growth and overtake majority market share by 2027.

[10] A Worldwide Cost-based Design and Optimization of Tilted Bifacial Solar Farms



(Figure 3. World Market Share of monofacial and bifacial modules as function of time, showing growth from 2017 through 2022 and prediction of distribution from 2023–2033.)[11]

As bifacial panels continue to decrease in cost and industry adoption grows, the utilization of vertical panel orientations will undoubtedly grow as well. While the typical tilted solar configuration will likely remain the most popular, vertical bifacial panels facing east-west are likely to see a boost as well — especially in high albedo areas like deserts or northern regions that receive lots of snow. Vertical panels will also see growth in areas like agriculture and residential fencing as prices continue to fall. The global agrivoltaic market in general is set to reach over $11 billion in value with a 5.6% compound annual growth rate (CAGR), with the primary crops being root vegetables since they will not grow tall enough to shade the panels.[12] Vertical bifacial panels will play a key factor in agrivoltaics as they take up less farm land, produce an efficient energy output, and are conducive to regular agricultural practices. Farms and vertical solar farms can coexist more readily than tilted panels and will see further adoption in the agrivoltaics industry with bifacial panel prices falling.

Conclusion

[11] Performance of bifacial PV modules under different operating conditions in the State of Minas Gerais, Brazil

[12] Agrivoltaic Market Size - By System Design (Fixed, Dynamic), By Harvest Type (Root Crops, Vegetables, Fruits), By Placement (Ground Mounted, Shading Nets, Greenhouses), 2025 – 2034

With the bifacial solar panel global market quickly trending toward a majority share for all new solar farms built, vertical bifacial panels are likely to see growth as well. Though many developers will continue utilizing south-facing tilted orientations, certain use cases are optimal for vertical panels depending on factors like location, albedo, and land use. In desert climates and snowy regions with high albedo, vertical bifacial panels take advantage of boosted energy output resulting from the reflected irradiance. In the winter months with lots of snow, east-west vertical bifacial panels can even outperform the standard tilted arrays. Vertical panels also take up less land than their tilted counterparts, creating interesting project economics as areas with more expensive land could sway decisions to vertical configurations. Agrivoltaics specifically is an optimal market for vertical bifacial panels to excel since they can easily be co-located with many farms. The prime advantages for incorporating vertical panels in agriculture are their minimal land coverage and antisoiling properties that allow for little maintenance. Some of the other benefits from vertical panels — dual-energy production peaks, no heat island effect, and panels running cooler — apply more broadly across sectors and allow more room for increasing implementation. Vertical bifacial solar panels, while not the perfect solution for the solar industry, should still be incorporated into utility-scale projects and agrivoltaics to help compensate for the shortcomings of tilted panels. By adding east-west vertical solar farms to the generation mix in the U.S. or even globally, overall grid stability will improve and reliance on gas peaker plants will decline.

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