

# Solar power from 'the dark side' unlocked by a new formula

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Most of today's solar panels capture sunlight and convert it to electricity only from the side facing the sky. If the dark underside of a solar panel could also convert sunlight reflected off the ground, even more electricity might be generated.

Double-sided [solar cells](#) are already enabling panels to sit vertically on land or rooftops and even horizontally as the canopy of a gas station, but it hasn't been known exactly how much electricity these panels could ultimately generate or the money they could save.

A new thermodynamic formula reveals that the bifacial cells making up double-sided panels generate on average 15% to 20% more sunlight to electricity than the monofacial cells of today's one-sided solar panels, taking into consideration different terrain such as grass, sand, concrete and dirt.

The formula, developed by two Purdue University physicists, can be used for calculating in minutes the most electricity that bifacial solar cells could generate in a variety of environments, as defined by a [thermodynamic limit](#).

"The formula involves just a simple triangle, but distilling the extremely complicated physics problem to this elegantly simple formulation required years of modeling and research. This triangle will help companies make better decisions on investments in next-generation solar cells and figure out how to design them to be more efficient," said Muhammad "Ashraf" Alam, Purdue's Jai N. Gupta Professor of Electrical and Computer Engineering.

In a paper published in the *Proceedings of the National Academy of Sciences*, Alam and coauthor Ryyan Khan, now an assistant professor at East West University in Bangladesh, also show how the formula can be used to calculate the thermodynamic limits of all solar cells developed in the last 50 years. These results can be generalized to technology likely to be developed over the next 20 to 30 years.

The hope is that these calculations would help solar farms to take full advantage of bifacial cells earlier in their use.

"It took almost 50 years for monofacial cells to show up in the field in a cost-effective way," Alam said. "The technology has been remarkably successful, but we know now that we can't significantly increase their efficiency anymore or reduce the cost. Our formula will guide and accelerate the development of bifacial technology on a faster time scale."

The paper might have gotten the math settled just in time: experts estimate that by 2030, bifacial solar cells will account for nearly half of the market share for [solar panels](#) worldwide.

Alam's approach is called the "Shockley-Queisser triangle," since it builds upon predictions made by researchers William Shockley and Hans-Joachim Queisser on the maximum theoretical efficiency of a monofacial solar cell. This maximum point, or the thermodynamic limit, can be identified on a downward sloping line graph that forms a triangle shape.

The formula shows that the efficiency gain of bifacial solar cells increases with light reflected from a surface. Significantly more power would be converted from light reflected off of concrete, for example, compared to a surface with vegetation.

The researchers use the formula to recommend better bifacial designs for panels on farmland and the windows of buildings in densely-populated cities. Transparent, double-sided panels allow solar power to be generated on farmland without casting shadows that would block crop production. Meanwhile, creating bifacial windows for buildings would help cities to use more renewable energy.

The paper also recommends ways to maximize the potential of bifacial cells by manipulating the number of boundaries between semiconductor materials, called junctions, that facilitate the flow of electricity. Bifacial

cells with single junctions provide the largest efficiency gain relative to monofacial cells.

"The relative gain is small, but the absolute gain is significant. You lose the initial relative benefit as you increase the number of junctions, but the absolute gain continues to rise," Khan said.

The formula, detailed in the paper, has been thoroughly validated and is ready for companies to use as they decide how to design bifacial [cells](#).

**More information:** Muhammad A. Alam et al. Shockley–Queisser triangle predicts the thermodynamic efficiency limits of arbitrarily complex multijunction bifacial solar cells, *Proceedings of the National Academy of Sciences* (2019). [DOI: 10.1073/pnas.1910745116](https://doi.org/10.1073/pnas.1910745116)

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