

The shading advantage of BC depends on the number and arrangement of shaded cells

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Does back-contact technology really beat TOPCon in practice?

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Back-contact's advertised shading advantage has practical limits. Research comparing it with TOPCon modules shows where that advantage ends and why installers should consider the size and pattern of shadows alongside everyday energy yield.

The advantages of back-contact (BC) technology under partial shading have been widely advertised. For project developers and installers, however, the key question is whether that advantage applies to the shading patterns they actually encounter. In the configuration tested in a 2026 study, BC's advantage ended when four or more cells were shaded across different substrings within one string. A chimney casting a broad shadow across a rooftop, a vent pipe shading several cells, a tree branch stretching across a module or one PV row shading another can affect multiple cells. These practical shading patterns need to be considered before assuming that BC will deliver a meaningful advantage over tunnel oxide passivated contact (TOPCon).

For some years now, BC modules have been marketed as particularly suitable for partially shaded roofs. The technical basis is solid: BC cells can continue to conduct electricity under certain shading conditions, which delays the activation of the module's bypass diodes and reduces power losses due to light, local shading.

A peer-reviewed study by scientists from Trinasolar's State Key Laboratory of Photovoltaic Science and Technology (SKL) and Nanchang University examined the limits of that advantage. The researchers compared complete BC and TOPCon modules under progressively larger shaded areas, as well as under row-to-row shading typical of ground-mounted systems. A separate 2026 study by Liu et al. examined more complex shading patterns, including shading across different substrings within one string.

The BC advantage stops at four shaded cells

The 2026 study identifies a clear threshold for the configuration tested. When shading crossed different substrings within one string, BC's advantage disappeared once four or more cells were affected. Both technologies then experienced approximately 50% power loss because the shaded string stopped contributing, leaving only the unshaded string generating. With three or fewer shaded cells under those conditions, BC retained an advantage. The separate 2025 study found an advantage when fewer than three cells within a substring were shaded.

That gives installers a practical rule of thumb: the size and shape of the shadow matter as much as the fact that the module is shaded.

Consider a narrow shadow from a leaf, bird droppings or a thin cable. If it affects only one or two cells, BC may retain more output than TOPCon.

Now consider a typical rooftop installation. A chimney, vent pipe, antenna or nearby tree branch can cast a shadow across several adjacent cells or modules. These broader shadows may fall outside the conditions in which BC retained an advantage in the tests. If shading cannot be prevented, its size and arrangement are critical factors for performance.

The same applies to larger obstructions. A neighbouring building may create a broad shadow covering many cells and modules. In such a case, the BC advantage seen in laboratory demonstrations of isolated shaded cells should not be assumed to translate into a comparable system-level gain.

The 2025 study examined bypass activation by progressively increasing the shaded area on individual cells under standard test conditions of 1,000 W/m² irradiance and 25 °C cell temperature. The results showed that BC's advantage persists only while the number of shaded cells remains below the point at which the bypass diode is activated.

For installers, this means that 'better in partial shade' is not a sufficient reason on its own to specify BC. The actual obstruction needs to be considered.

Row-to-row shading: no meaningful BC advantage

The distinction becomes even more important outside the residential rooftop market.

In ground-mounted and utility-scale systems, the most common shading event is not a single leaf or narrow pipe. It is one row of modules casting a shadow onto the row behind it, particularly in the morning and late afternoon.

The study found essentially no meaningful performance difference between BC and TOPCon under this type of row-to-row shading. The researchers tested both short-side and long-side row shading and found that, once the bypass diodes became active, the two technologies behaved similarly.

For project developers and owners, this is a critical practical point.

If the installation is designed with rows of modules and the dominant shading scenario is one row shading another, the shading condition of greatest concern for that layout is also one in which BC's advertised shading advantage completely disappears.

The same principle can apply to larger commercial ground-mounted arrays where row spacing and mounting geometry determine the daily shading profile. Module selection should therefore not assume that a BC module will automatically deliver higher output simply because the site experiences shading.

Why the advantage disappears

In the configuration discussed in the 2025 study, BC cells entered reverse breakdown at around minus 5 V, while bypass activation was associated with a substring negative bias of around minus 15 V. Under mild shading, BC's low breakdown voltage allows a shaded cell to continue carrying current and can delay bypass activation.

As shading becomes more severe, that electrical benefit can be lost. In the cross-substring tests, the shaded string stopped contributing and only the unshaded string continued generating. The outcome depends on the module configuration and the shading pattern.

In practical terms, a narrow shadow can be a module-selection issue; a broad shadow is more often a system-design issue.

That is why installers still need to look at roof geometry, obstruction height, string configuration and shading throughout the day rather than relying solely on the cell technology. System design comes first.

Where TOPCon can matter more: everyday energy yield

Shading is important, but it is only one part of the operating conditions a PV system experiences. A chimney may cast a shadow for several hours a day. A tree may cause localised shading at certain times. But every installation also experiences changing irradiance from clouds, diffuse light, rain, winter conditions, dawn and dusk. These low-light conditions can account for a much larger share of operating hours over the system's lifetime.

This is where TOPCon has shown strengths in long-term field performance. Outdoor monitoring programmes have reported higher cumulative energy yields for TOPCon modules, associated with factors including low-light response, temperature behaviour and long-term stability. A four-year field evaluation reported in PV Magazine found that TOPCon's generation advantage over the BC modules tested increased over the monitoring period.

For decision makers, the distinction is straightforward: a module's performance during a few specific shading events should be weighed against how it performs during thousands of hours of normal operation.

Conclusions

For module selection and system design, the research points to three practical considerations:

Light, localised shading: BC can retain more output when only a small number of cells are affected. The limits differ between the two studies and their tested shading patterns, as described above.

Larger rooftop shadows: chimneys, vents, tree branches, dormers and neighbouring structures can shade multiple cells. BC's advantage under isolated cell shading should not be assumed to apply to these broader shadows.

Ground-mounted systems: the 2025 study found no meaningful BC advantage under the row-to-row shading conditions tested.

The implication is not that one technology should always replace the other. Rather, module selection should start with the shading pattern an installer actually expects to see on the site.

The shading comparison also needs to be considered alongside everyday energy yield. Field tests reported by Trinasolar have shown higher generation per watt for the TOPCon modules tested under low-irradiance conditions, an aspect installers should also consider when selecting modules.

At Trinasolar, we use several cell technologies to suit different applications. We help customers choose the technology that best suits their installation and supports its performance over the long term.

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Ground-mounted arrays can experience row-to-row shading