

TOPCon Modules Outperform P-type BC by Up to 6.95% in Energy Yield

A study in Kagoshima shows that the latest generation of tunnel oxide passivated contact (TOPCon) modules surpass P-type BC modules on energy yield over the initial month of a 1-year period. The TOPCon product showed an average energy yield of **2.22%** and maximum **6.95%** higher than its P-type counterpart.

Background of the Project:

Most PV manufacturers are now well underway with the switch to N-type primarily TOPCon technology, rolling out to mainstream installations. In the past few months, the photovoltaic industry has debated over technical route of XBC. The manufacturers promised more rated power and front-side efficiency because there is no grid line on the front of the product. And as they make their way into some pilot projects, we can see how these claims play out in the field under various climate conditions. Many studies have been carried out already, and the signs so far are good for TOPCon.

One such study recently confirmed an average 2.22% (up to 6.95%) gain of TOPCon versus P-type BC in normalized energy yield (energy generated per unit of capacity) over an initial one month period of September 12 to October 11, 2024. German company TÜV NORD carried out the test in Kagoshima (31°35'2.8"N, 130°32'32.9"E), Japan

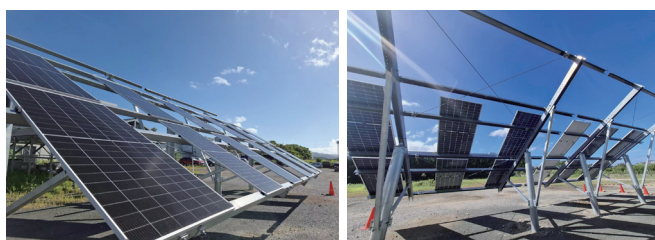


Figure 1: Project Picture

Project Introduction:

Three module types were installed at the site: a N-type TOPCon module rated power 575W from Jinkosolar, a 580W P-type BC module and a 605W N-type BC module. The test installation comprised two modules of each type, installed on fixed tilt racking 20°, 1.2 meter above the ground. The sample specifications are as follows:

Cell Technology	Module Size(mm)	Module type
N-type TOPCon	2278x1134x30	Dual Glass
N-type BC	2278x1134x30	Single Glass
P-type BC	2278x1134x30	Dual Glass

Test Results:

From September 12 to October 11, 2024, we tested the above technologies. The samples' initial power was measured using SAT without spectral correction. Power output data was gathered with a high-precision CR1000X system for individual components. TOPCon module generated 136.86 kWh/kW, P-type BC 133.87 kWh/kW, N-type BC 129.98 kWh/kW. Thanks to its higher bifaciality and lower temperature coefficient, when normalized based on each module power rating, the module achieved a yield 2.22% higher than P-type BC and 5.29% higher than N-type BC.

In sunny and cloudy days during the period, TOPCon modules energy yield consistently remains 2%-3% higher than P-type BC

modules and 5%-6% higher than N-type BC modules. The highest yield gain of TOPCon modules over P-type BC occurred on October 2, a rainy day, generating 6.95% more electricity per kilowatt than the P-type BC modules. While TOPCon outperformed N-type BC up to 9.06% on October 6, still a rainy day. It proves that even in low light condition, TOPCon demonstrates better generation capability due to less current leakage and higher bifaciality compared to XBC counterparts.

Jinko's TOPCon module also achieved the highest performance ratio of the three. Performance ratio compares the actual energy yield to a calculation based on the power rating and weather conditions. TÜV NORD measured a 94.19% performance ratio for the TOPCon module, with the other two trailing slightly behind, 91.99% for P-type BC and 89.29% for N-type BC. The future data validation plan will involve swapping channels and component installation positions to minimize systematic differences.

Date	Jinko TOPCon	N-type BC	P-type BC	VS N-type BC	VS P-type BC	MaxT	MinT	Weather
9.12	6.398988	6.086851	6.220883	5.13%	2.86%	32 C	24 C	Sunny
9.13	7.032675	6.752257	6.798867	4.15%	3.44%	31 C	24 C	Cloudy
9.14	4.076707	3.821927	4.046404	6.67%	0.75%	30 C	24 C	Light Rain
9.15	4.747012	4.483044	4.702885	5.89%	0.94%	31 C	26 C	Overcast
9.16	3.706624	3.486233	3.699521	6.32%	0.19%	31 C	25 C	Light rain
9.17	6.344481	6.033923	6.169520	5.15%	2.84%	32 C	24 C	Light rain
9.18	6.383120	6.098052	6.213230	4.67%	2.73%	32 C	25 C	Cloudy
9.19	4.796877	4.480227	4.641855	7.07%	3.34%	31 C	26 C	Cloudy
9.20	4.831553	4.589342	4.683953	5.28%	3.15%	31 C	25 C	Cloudy
9.21	5.406449	5.130972	5.321491	5.37%	1.60%	30 C	24 C	Moderate rain
9.22	0.841222	0.828839	0.786902	1.49%	6.90%	27 C	24 C	Torrential rain
9.23	3.780254	3.592866	3.693484	5.22%	2.35%	25 C	21 C	Light rain
9.24	5.474552	5.098604	5.391197	7.37%	1.55%	28 C	21 C	Moderate rain
9.25	3.789664	3.596079	3.654878	5.38%	3.69%	28 C	22 C	Sunny
9.26	6.802809	6.584096	6.641159	3.32%	2.43%	29 C	22 C	Sunny
9.27	6.217378	5.974597	6.046015	4.06%	2.83%	31 C	21 C	Cloudy
9.28	3.993454	3.763985	3.889421	6.10%	2.67%	29 C	23 C	Light rain
9.29	5.625255	5.313951	5.603316	5.86%	0.39%	29 C	23 C	Cloudy
9.30	6.693182	6.315824	6.559950	5.97%	2.03%	28 C	22 C	Light rain
10.1	6.066464	5.825145	5.920800	4.14%	2.46%	28 C	21 C	Light rain
10.2	0.873878	0.869055	0.817101	0.56%	6.95%	23 C	21 C	Torrential rain
10.3	2.180212	2.106019	2.112448	3.52%	3.21%	22 C	20 C	Moderate rain
10.4	1.296143	1.255449	1.228261	3.24%	5.53%	23 C	21 C	Torrential rain
10.5	4.084567	3.796805	4.054606	7.58%	0.74%	26 C	20 C	Light rain
10.6	3.762504	3.449920	3.730496	9.06%	0.86%	28 C	22 C	Light rain
10.7	2.088996	2.022614	2.021919	3.28%	3.32%	27 C	22 C	Light rain
10.8	0.744837	0.714775	0.713378	4.21%	4.41%	26 C	20 C	Cloudy
10.9	6.722295	6.400842	6.609123	5.02%	1.71%	25 C	17 C	Light rain
10.10	6.706093	6.435122	6.582395	4.21%	1.85%	25 C	17 C	Sunny
10.11	5.392796	5.076108	5.333318	6.24%	1.12%	25 C	18 C	Light rain

