# O D (L LID) H Y G N- C P- N ,CN

## Highlights:

**1. Energy yield performance**: the energy yield gain of n-type TOPCon (Group 1) versus p-type PERC (Group 2) with fixed axis was **3.69%**.

**2. Degradation**: the average degradation of Group 1 (TOPCon with fixed axis) and Group 2 (PERC with fixed axis) is **0.51%** and **1.38%**, respectively. Light induced degradation of TOPCon is much less than PERC.

The PERC solar cells are rapidly approaching the upper practical limit of achievable efficiency for that cell architecture. Additionally, the PERC design uses p-type silicon wafers, which are susceptible to light-induced degradation (LID) caused by boron oxygen (BO) defects. Due to the fast-approaching efficiency threshold and BO LID, the solar industry has impressively transited away from PERC towards N-type which uses n-type silicon wafers, doped with phosphorus, rather than the p-type wafers commonly used in PERC cells.

In recent years, TOPCon technology has been transferred from laboratory to manufacturing, which is more crucial to investigate it in outdoor performance. Thematically, N-type TOPCon solar cells do not suffer BO LID, several laboratory test reports and studies have proven that far less presence of light-(LID) and elevated temperature-induced degradation (LeTID) in n-type cells than PERC cells. But whether the performance of PV modules in real-world conditions may differ from laboratory test results, especially for the degradation, which are highly sensitive to the surrounding environment, such as irradiance, temperature, humidity. Therefore, an outdoor energy yield and performance stability comparison study performed on PERC and TOPCon modules was conducted by CPVT (National Photovoltaic Quality Inspection Center) in Yinchuan (38°34′57.77″N, 106°0′55.72″E) Ningxia, north western of China.

Two groups of total 20 pieces of bifacial modules of two different technologies were selected from JinkoSolar, and each bifacial module contains 144 pieces of the half-cut cell, as shown in Table 1)

| Group | Module | Number | Type | Mounting System |
|---|---|---|---|---|
| 1#N-TOPCon | JKM555N-72HL4-BDV | 10 | Bifacial | Fixed axis |
| 2#P-PERC | JKM540M-72HL4-BDVP | 10 | Bifacial | Fixed axis |

Table 1: Sample information

The PASAN Sun simulator measured the front and rear sides' electrical characteristics. The bifaciality and the light efficiency at 60kWh/m² were also measured and calculated. The outdoor energy generation was measured by DC meters in a 1-min interval.

## Experimental Photovoltaic Test Facility

Two groups of TOPCon and PERC bifacial modules were installed on a fixed axis with a tilt angle of 40° (as shown in Figure 1) Moreover, the pitch and clearance of each array were 10 m.

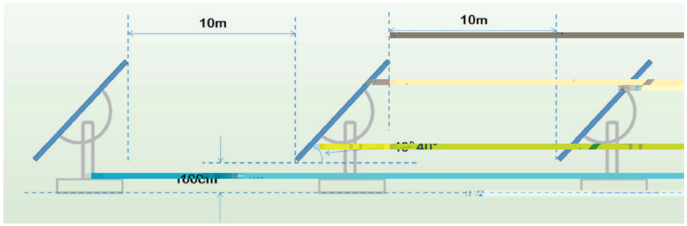


Figure 1. Fixed axis

The monthly irradiation of front and rear side and albedo of testing groups (measured from September 2022 - March 2023) are shown in Table 2 and Figure 3.

| Month | Fixed Axis- Cumulative Irradiation(kWh/m²/month) | | Reflectance (%) |
|---|---|---|---|
| | Front side | Rear side | |
| 2022-09 | 175.44 | 20.25 | 11.54 |
| 2022-10 | 137.67 | 15.02 | 10.91 |
| 2022-11 | 123.39 | 11.86 | 9.61 |
| 2022-12 | 119.57 | 10.51 | 8.79 |
| 2023-01 | 153.75 | 14.36 | 9.34 |
| 2023-02 | 103.42 | 12.15 | 11.75 |
| 2023-03 | 197.15 | 22.64 | 11.48 |

Table 2: Irradiation and reflectance

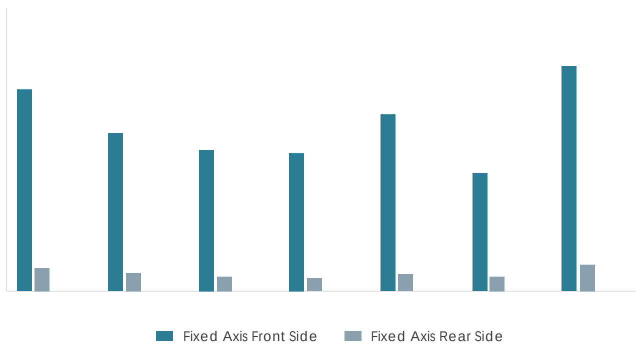


Figure 3. Monthly cumulative irradiation

The monthly energy yield of two groups (measured from September 2022-March 2023) were shown in Table 3 and Figure 4. And the energy yield per watt (Wh/W) was calculated according to Formula 1 was indicated in Table 3 and Figure 4.

## Calculator:

**Formula 1:**

**Formula 2:**

| Month | Group 1-Power generation per watt (Wh/W) | Group 2-Power generation per watt (Wh/W) |
|---|---|---|
| 2022-09 | 5.64 | 5.44 |
| 2022-10 | 4.57 | 4.39 |
| 2022-11 | 4.45 | 4.29 |
| 2022-12 | 4.90 | 4.74 |
| 2023-01 | 5.01 | 4.81 |
| 2023-02 | 4.35 | 4.19 |
| 2023-03 | 6.11 | 5.88 |
| **Average** | 5.00 | 4.82 |

Table 3: Power generation per watt

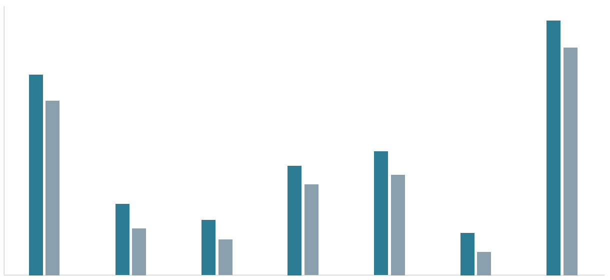


Figure 4. Power generation per watt

The performance degradation of N-type and PERC were shown in Table 4 and Table 5,respectively.

| | Isc(A) | Voc(V) | Imp(A) | Vmp(V) | Pmax(W) | FF(%) | Eff.(%) |
|---|---|---|---|---|---|---|---|
| Group 1 | 13.59 | 51.41 | 12.93 | 43.45 | 561.8 | 80.44 | 21.77 |
| Group 2 | 13.68 | 49.54 | 13.00 | 41.33 | 537.3 | 79.30 | 20.82 |

Table 4: Initial results of laboratory test data (mean)

| | Isc(A) | Voc(V) | Imp(A) | Vmp(V) | Pmax(W) | FF(%) | Eff.(%) |
|---|---|---|---|---|---|---|---|
| Group 1 | 13.57 | 51.57 | 12.90 | 43.34 | 558.9 | 79.90 | 21.66 |
| Group 2 | 13.63 | 49.14 | 12.94 | 40.95 | 529.9 | 79.14 | 20.53 |

Table 5: Period results of laboratory test data (mean)

## Conclusions:

**1. Energy yield performance**: the energy yield gain of n-type TOPCon (Group 1) versus p-type PERC (Group 2) with fixed axis was **3.69%.**

**2. Degradation:** the average degradation of Group 1 (TOPCon with fixed axis) and Group 2 (PERC with fixed axis) is **0.51%** and **1.38%**, respectively. Light induced degradation of TOPCon is much less than PERC.

*D :*

*-J K（2022.09-2023.3)*


Group 1. N-type Test Site

Group 2. P-type Test Site