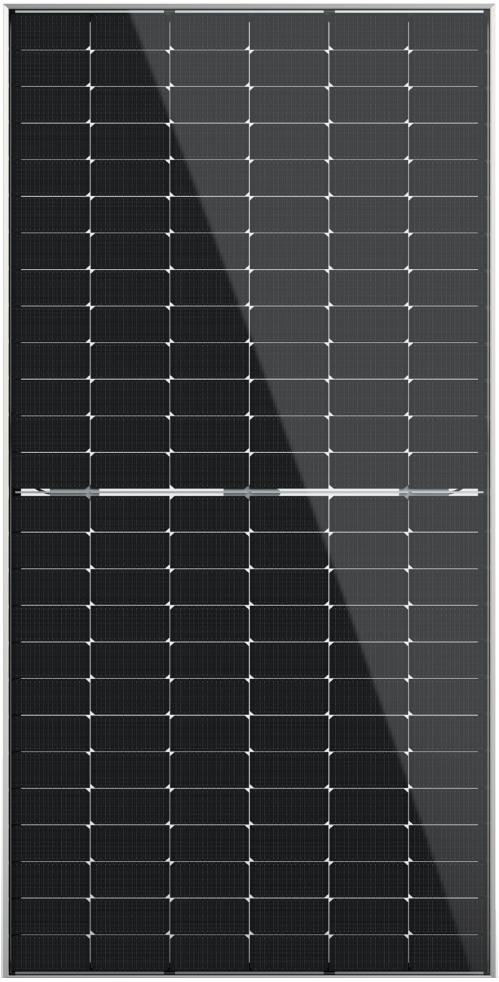
Product White Paper

Building **Your Trust** in Solar

Tiger Neo N-Type TOPCon Module



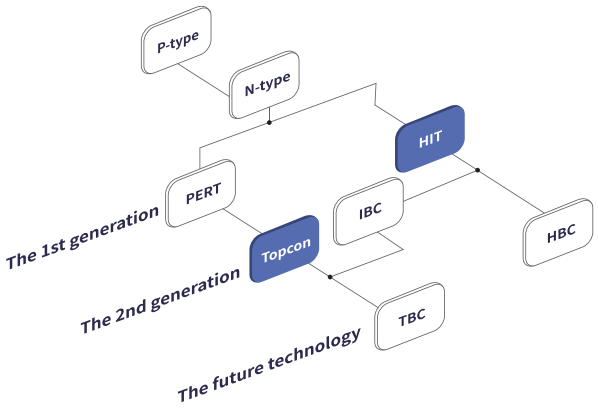
1. Background

1.1 The technology market trends of Tiger Neo N-type module

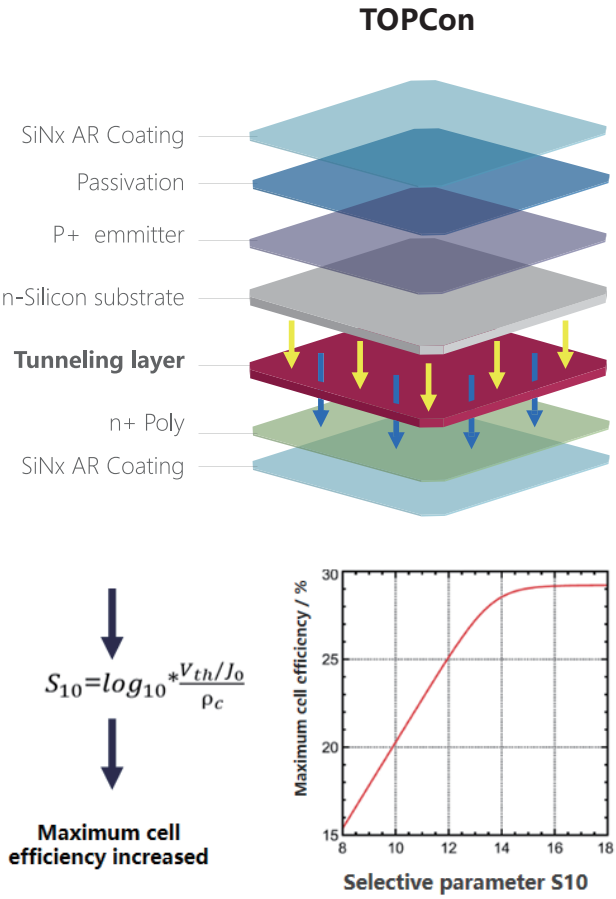
Most are familiar with traditional P-type cell technology. With large-scale manufacturing of monocrystalline silicon wafers, P-type mono PERC cell technology has been deployed on a large majority of projects since 2017. Mainstream module manufacturers have used mono PERC due to a simple manufacturing process, low cost, and cell conversion efficiency improvements.

However, the efficiency of PERC cells has approached a limit of 24.5%, and cost reduction has also slowed. Meanwhile, new cell technology is developing rapidly, and N-type cells are most likely to replace P-type cells to become the next-generation mainstream technology.

The current technical roadmap for N-type cells is shown below. Among the options, TOPCon and HIT are the primary focus of the current N-type technology.



The traditional P-type cell uses a boron-doped silicon wafer substrate, which easily forms a boron-oxygen pair after initial illumination. It will lead to light-induced degradation after a recombination center is formed by trapping electrons in the silicon wafer substrate. In contrast, the N-type cell silicon wafer substrate is doped with Phosphorus, so there is almost no loss of recombination center formed by the boron-oxygen pair, which greatly reduces light-induced degradation. For example, in TOPCon technology, the structure of the tunnel oxide layer further reduces the sub-surface recombination rate, which greatly optimizes the cell conversion efficiency, and the upper limit can reach 28.2%~28.7%.



The TOPCon cell applies cutting-edge and high-efficiency passivation contact technology, and uses a micro-nano tunneling oxide layer and a carrier-selective microcrystalline silicon film laminated functional structure on the back. This innovative structure demonstrates a two-way improvement in passivation performance and electrical conductivity, which brings significant improvements in cell conversion efficiency and power generation performance. The highest efficiency of N-type HOT2.0 cell is close to 25% in mass production, showing broad application prospects.

In short, TOPCon and HIT achieve efficiency improvements through passivation to reduce the number of sub-surface recombination rates. The former uses tunneling oxide layers and HIT uses intrinsic amorphous silicon film. The differences in the methods lead to the respective manufacturing processes, resulting in the difference in the commercial cost between the two.

1.2 Effect of High-efficiency module on LCOE

With the rapid development of renewable energy around the world,

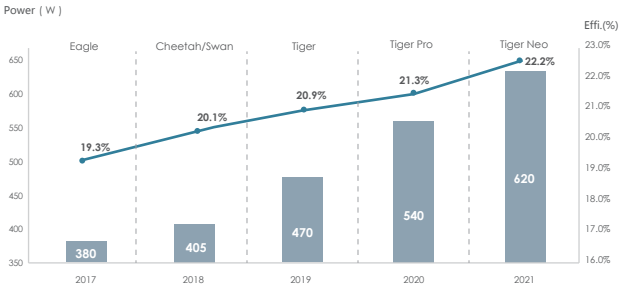
land resources for projects are becoming increasingly scarce in many regions. Optimizing profitability and land resource by selecting the highest efficiency module is an important topic.

$$LCOE = \frac{\text{Initial Cost(EPC Cost included)} + \sum_{n=1}^{25} \frac{L_n + M_n + IS_n - TS_n}{(1+r)^n} + \sum_{n=1}^{m} I_n \cdot \frac{RV}{(1+r)^n}}{\sum_{n=1}^{25} \frac{E_n}{(1+r)^n}}$$

The LCOE drives market demand, so high-power and high-efficiency modules have become a trend, and the N-type module has an obvious effect on reducing project costs.

JinkoSolar adheres to a philosophy of high power and high efficiency, and the company realizes the simultaneous enhancement of module power and efficiency by integrating large silicon wafers, multiple form factors (including 78 cell specification), multiple busbars, and stitch welding technologies. JinkoSolar's high-efficiency N-type monocrystalline silicon single-junction cell technology has been calibrated by JET testing laboratory, an authoritative third-party testing and certification organization in Japan, to achieve a maximum conversion efficiency of 25.4% for the full-area cell, creating a new world record for the conversion efficiency of large-area N-type single crystal passivation contact (TOPCon) cell. At this moment, N-type TOPCon has an obvious advantage in mass production efficiency, cost control, and market share.

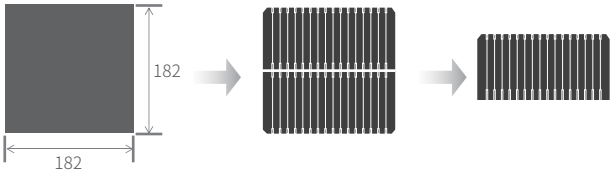
In the long run, as TOPCon cells develop, the constant improvement in efficiency will continue to increase the power difference between N and P-type modules. The process optimization and new technology application will also continuously reduce costs.



2. Technical highlights

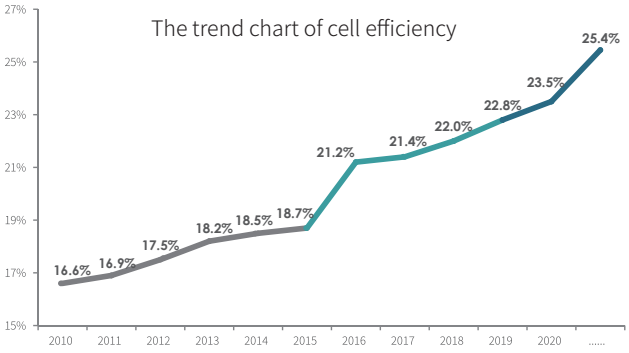
2.1 Technical advance—M10 silicon wafer

The size of M10 silicon wafer is uniform to 182mm*182mm



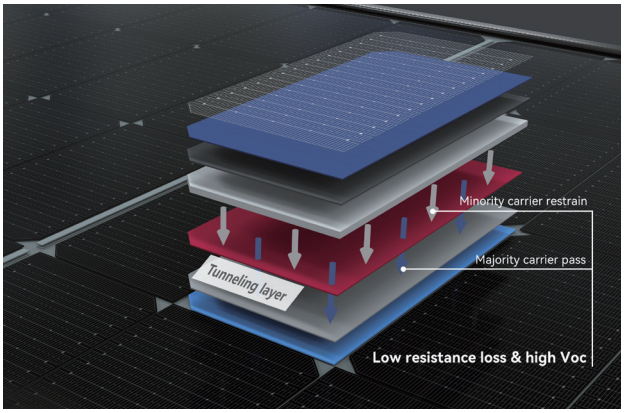
Industrial end: the industrial chain includes silicon wafers, cells, modules and auxiliary materials to reduce resource waste and promote benign development;

Customer end: the module size is nearly uniform, the system design is simplified and the upstream and downstream collaboration are improved.



2.2 TOPCon technology

TOPCon cell technology is a new passivated contact solar cell developed by the Fraunhofer Solar Energy Institute in Germany. Passivation is a key technology in determining maximum efficiency of the cell, as shown in the picture below.



2.3 Tiger Neo module with high efficiency

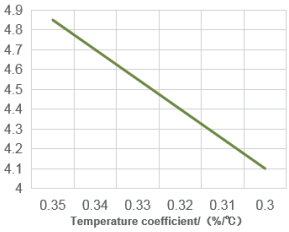
2.3.1 Temperature coefficient

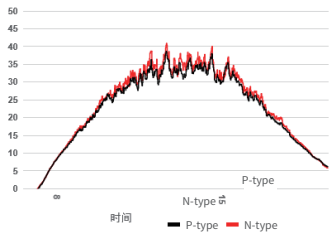
The temperature coefficient of a similar P-type module is -0.35%/°C while that of N-type is modified to -0.30%/°C. This means the power generation performance is particularly outstanding at high temperature.

Tiger Neo's power output will increase with the better-temperature coefficient (0.75% higher compared with PERC).

Under the same external environment, Tiger Neo's operating temperature is lower (>1 % compared with the same specification P type) and the heat loss is greatly reduced.

Under high temperature condition, the advantage will further expand (~2% higher than P-type).





2.3.2 Bifacial factor

The bifacial factor or traditional PERC module is 70% while that of TOPCon module is modified to 85%. The corresponding power gain is around 2.03%. According to the formula, the power gain of traditional PERC module due to the rear side power gain is 9.45% while that of a TOPCon module is 2 % more due to the 15% bifacial factor increase (under STC condition and average ground reflectivity).

Power gain contrast due to the increase of bifacial factor

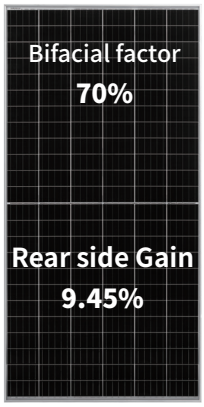
PERC: BSI*Bifi (70%) ≈9.45%

TOPCon: BSI*Bifi (85%) ≈11.48%

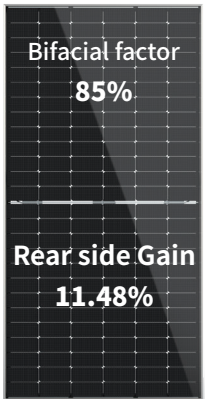
P*=Pfront* (1+BSI * Bifi)

*Bifi：The module bifacial factor

*BSI：Bifacial stress irradiance coefficient (depending on real irradiance & ground reflectivity)



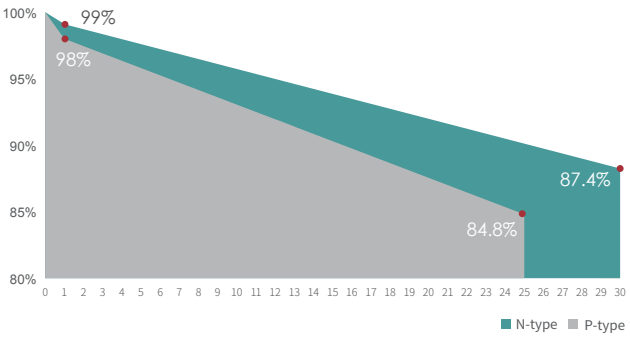
P-type



N-type

2.3.3 Better warranty

The power warranty can achieve 30 years compared to a traditional P-type module. The first year degradation is lower than 1% which means the power output at year 30 is guaranteed to be at least 87.4%.



First year degradation⩽ 1%

The linear degradation (2~30 years)⩽ 0.4%

3. System design

3.1 The combination of inverters

Inverter upgrades for high-current modules continue, and as of Q2 2022, the vast majority of inverters are compatible with existing Tiger Neo high-current modules.

*The maximum operating current is calculated with the irradiance of 1000 in the standard working condition.
The actual working condition is lower than this value, and the compatibility is easier to meet

Satisfiability unsatisfiability

Scenario	Module	Impp	Supplier	Imax / string	Imax (expected)	Deadline (expected)
Residential	60N-mono	13.49A	**Growatt**	13.5A	–	–
			Solis	16A	–	–
			SMA	Compatible	–	–
			Goodwe	13A	15A	**2021 Q4**
C&I	72N-mono	13.65A	Huawei	13A	16A	**2022 Q2**
			Sungrow	13A	15A	**2022 Q1**
			SMA	Compatible	–	–
Utility	78N-bifacial	15.34A (15%bifacial gain)	Huawei	15A	16A	**2022 Q2**
			Sungrow	20A	–	–
			Solis	16A	–	–

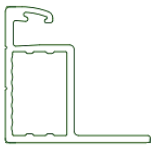
3.2 The mounting system

High mechanical strength design

Enhanced frame design

Thicker material

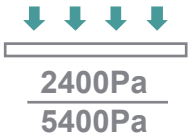
Thicker cavity



Multiple installation modes

Bolts installation

Clamp installation



4. Economic analysis

4.1 System advantage analysis

The Tiger Neo has a power advantage over the 182P 545W and the 210P 600W, increasing total power by 1.58% and 4.37%.

Module	210-60P	182-72P	182-72N
Power（W）	600	545	560
Isc(A)	18.42	13.95	14.13
Voc(V)	41.7	49.92	50.67
Module no. /String	31	26	26
String/Tracker	3	4	4
Total power（W）	**55800**	**56680**	**58240**
Power gain	**-**	**+1.58%**	**+4.37%**

* Based on the historical lowest temperature -20°C calculation

4.2 LCOE analysis

4.2.1 200MW AC power station in Inner Mongolia

JinkoSolar's Tiger Neo module has a maximum power of 620W, which can increase power by 15-20 W compared to the P-type. Such an increase in power greatly changes the market's perception of P-type modules, especially in projects using trackers.

4.2.1.1 Initial cost analysis

The following example uses an Inner Mongolia 200MW DC power station (comparing the 182-N-605W module and 210-P-660W module). The former can connect more strings on a single tracker than 210 due to its size advantage, and the total power of a single tracker is much higher. Both the original 3-string VS 2-string or the newer 4-string VS 3-string have resulted in a reduction in the number of trackers required for a utility project using 182 Tiger Neo modules, and a significant reduction in BOS costs and cable costs.

At the same time, the high efficiency of N-type modules also decreases the land lease cost. The above two points result in the BOS decrease of nearly 1.18%. More importantly, the Tiger Neo series are highly efficient at power generation throughout the year, therefore achieving higher power output over the life cycle.

The table below shows the design of the project (tracker)

Cell	182-78N	210-66P
Power	605W	660W
Efficiency	21.64%	21.25%
Length (mm)	2465	2384
Width (mm)	1134	1303
Voc(V)	54.76	45.90
1500V single series/psc	25	30
Tracker installation fee	76.21%	80.19%
String/ tracker	4	3
No. of tracker	Base	101.9%
Power/ tracker （W）	**60500**	**59400**
Tracker length （m）	Base	Base+4m
No. of column	Base	Base+1
Percentage (All column)	74%	80%

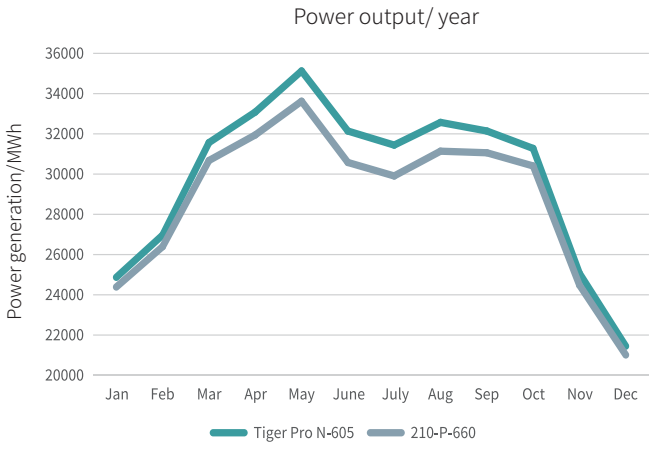
Tracker-theroy (/W)	Base	**104.2%**
BOS Cost	Base	**101.18%**

* 200MW AC power station in Inner Mongolia N：39.74°, E：99.21°

4.2.1.2 Power generation analysis

In Alxa of Inner Mongolia, the power generation advantage of N-type modules gradually increases in the spring, and the difference culminates at a maximum 5.1% in summer (June and July).The total annual power generation gap between N type and P type is about 12096MW.

Overall, the Tiger Neo series can reduce LCOE by more than 6% and increase IRR by 5.31% compared to the P type, which makes it the optimal choice for PV project investment.

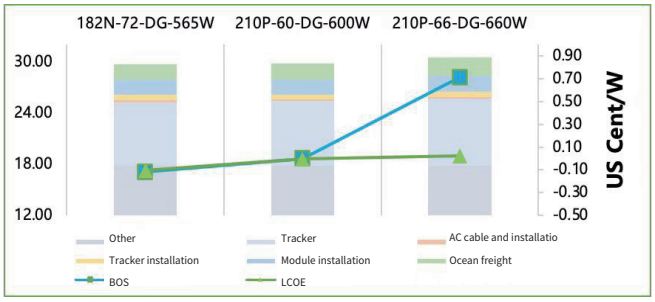


4.2.2 LCOE Analysis – utility overseas

In this economic analysis, two 2P tracker projects in Saudi-Arabia and Spain were selected for comparison. Saudi Arabia is located in the Arabian Peninsula of West Asia at 20-30° NORTH latitude. The sunshine condition is sufficient, with the average sunshine amount reaching 2200 kWh/m2, which is the site of many solar power stations. At the same time, Saudi Arabia has a lot of technical expertise and infrastructure to support the solar grid. Another notable feature of the Saudi project is its high sea freight cost (7189USD/ container). Spain also ranks among the world's leaders in solar power generation. In this economic analysis, the Spanish project also has significant sea freight costs (6000USD/ container).

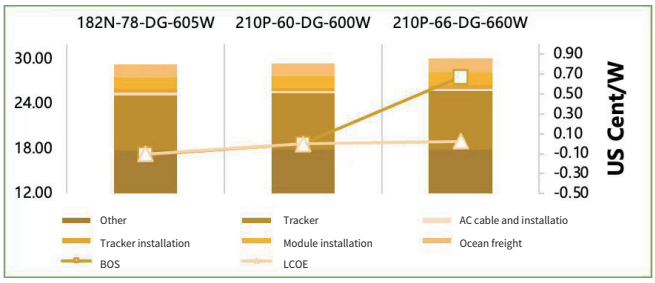
In Saudi Arabia's 2P tracker project, the 182N-72module saved significantly on mounting costs and cable costs compared to the 210P-60 and 210P-66 due to its better size, resulting in a 2.8% and 0.4% reduction in BOS costs, respectively, on the capex. Meanwhile, the 182N-72 with its outstanding conversion efficiency, excel- lent LID/LET-ID, and longer warranty compared to the 210P-60 and 210P-66 greatly improves the total power output of the whole life cycle, resulting in 6.2% and 4.94% lower LCOE, respectively. In the Spanish 2P tracker project, the 182N-78 module continued to have an advantage over the 210P-60 and 210P-66, with BOS reduced by 2.65% and 0.37%, while LCOE decreased by 4.78% and 3.84%, respectively.

It is worth noting that Tiger Neo (either 72 or 78 cells) is superior to the 210 module when sea freight costs are high. On the same shipping route, the total loading power of the 210P module packing scheme is less than that of the 182N, making the cost per watt of the 210P module less competitive. At the same time, the special support equipment cost and labor cost of 210 modules are also higher than those of 182N, which further increases the BOS of the system. In the above economic calculation and case analysis, the additional support equipment cost and labor cost required for the transportation of 210 modules have not been taken into account. Therefore, the gap between actual BOS and LCOE is larger.



Saudi Arabia 2P tracker

	182N-72	210P-60	210P-66
Power Class (W)	565	600	660
△BOS(US Cent/W)	–	▲2.8%	▲0.40%
△LCOE(US Cent/W)	–	▲6.2%	▲4.94%



Spain 2P tracker

	182N-78	210P-60	210P-66
Power Class (W)	605	600	660
△BOS(US Cent/W)	–	▲2.65%	▲0.37%
△LCOE(US Cent/W)	–	▲4.78%	▲3.84%

In conclusion, the 182 N-type module has better design specifications. Its high packaging density and easy handling make it very competitive, especially during a period of prolonged high cost logistics. The 182 N-type module is also the best investment choice for customers due to the lower LCOE it provides in real projects.