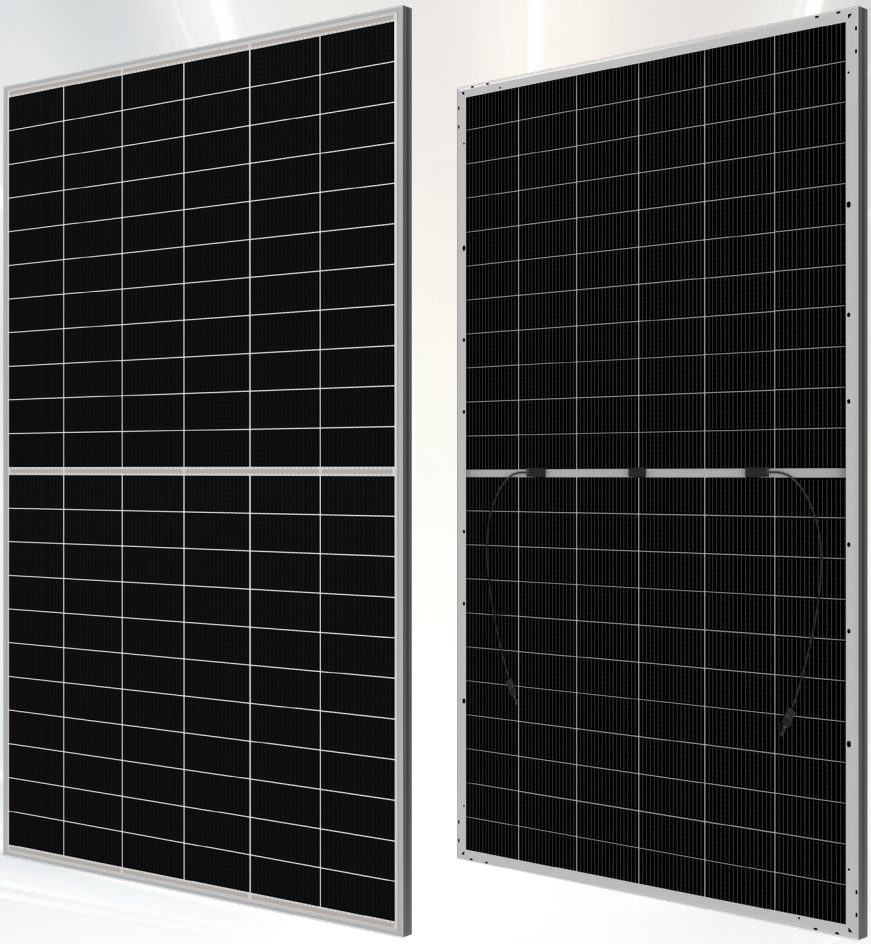
CanadianSolar



182 Pro
High Efficiency TOPCon Modules

Product White Paper

CSI Solar Co., Ltd.

2024.09

1.Introduction

Canadian Solar was founded in 2001 in Canada and is one of the world's largest solar technology and renewable energy companies, and having been publicly listed on the NASDAQ since 2006. CSI solar, the majority-owned subsidiary of Canadian Solar, has been listed on the Shanghai Stock Exchange's Sci-Tech Innovation Board (688472) in 2023. Canadian Solar has a global workforce of over 22,000 employees.

Canadian Solar is a leading manufacturer of solar photovoltaic modules, provider of solar energy and battery storage solutions, and developer of utility-scale solar power and battery storage projects with a geographically diversified pipeline in various stages of development. By end of 2024, the capacity will be: Ingot 50GW, wafer 50GW, cell 55GW, module 61GW, and 20GW energy storage and 8GW inverters.
Canadian Solar maintains sales and service subsidiaries in more than 20 countries and regions, with solar photovoltaic modules to customers more than 160 countries around the world.

With over 20 years of technological accumulation, Canadian Solar has developed a comprehensive core technology system, consistently leading the global photovoltaic industry in the number of patent applications and grants for several years. As of March 28, 2024, the company had filed a total of 4,508 patents, with 2,231 patents currently active. Canadian Solar has led or participated in the formulation of more than 20 international, national, and industry photovoltaic standards.

In 2024, Canadian Solar was awarded the 'Top PV Brand ' by EUPD Research and recognized as a 'Top Performer' by Kiwa PVEL among global module manufacturers. Additionally, since 2017, Canadian Solar has consistently been ranked as a Tier 1 solar module manufacturer by Bloomberg New Energy Finance (BNEF) and, in 2024, was also recognized as a Tier 1 energy storage product manufacturer by BNEF. As of the first quarter of 2024, Canadian Solar has provided global customers with over 125 GW of high-quality solar modules and more than 4.5 GWh of energy storage system products.

2.CSI TOPCon Module : Higher Power, More Reliable

CSI Solar is committed to enhancing the performance and dependability of its solar modules, while consistently delivering top-notch products to its customers. Through proactive exploration of cutting-edge module technologies, the company continually introduces products that boast increased energy output, including large-dimension wafers, N-type HJT cells, and TOPCon (Tunnel Oxide Passivated Contacts) modules. Since 2019, CSI Solar has been dedicated to the development of N-type TOPCon technology.

After years of dedicated research and development, CSI Solar has introduced its N-type TOPCon high-efficiency module, distinguished by its unwavering reliability and innovative design. This module is available in both 182*182mm and 210*210mm cells, offering flexibility for diverse applications. Moreover, it is offered in both single-glass and double-glass modules and various module formats and power outputs.

Furthermore, CSI Solar challenges conventional norms by optimizing module design to align with container dimensions. This evolution includes upgrading from the 182 TOPCon(182*182) to the 182 Pro TOPCon(182*210), leveraging in-house capabilities spanning from ingot production to cell and module manufacturing, thereby enhancing the product line comprehensively. The 182 Pro module offers innovative solutions for both distribution and utility-scale applications. By maximizing container space utilization and delivering higher power output, this advancement not only reduces Balance of System (BOS) costs and Levelized Cost of Energy (LCOE) but also adds significant value for customers.

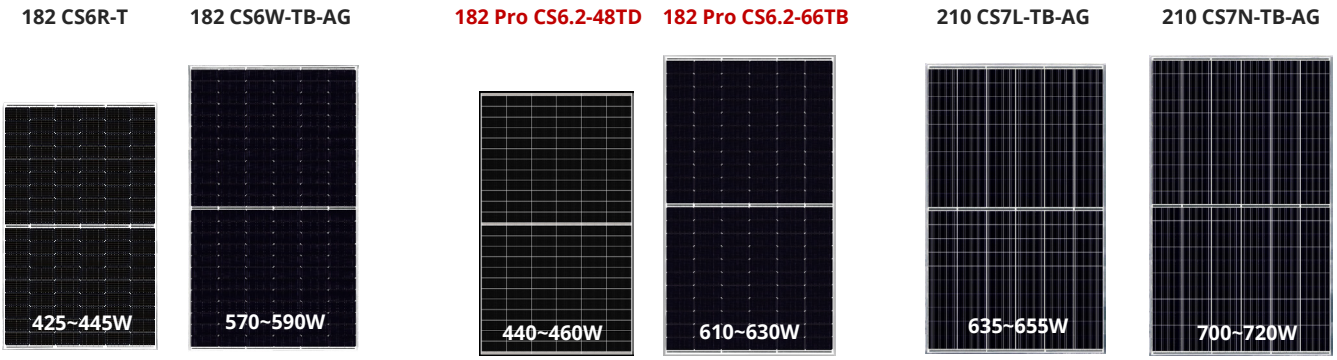


Figure 1. CSI TOPCon Module Family

Product Specifications	182		182Pro		210	
Module Power (W)	425~445	570~590	440-460	610~630	635~655	700~720
Module Type	CS6R-T	CS6W-TB-AG	CS6.2-48TD	CS6.2-66TB	CS7L-TB-AG	CS7N-TB-AG
Module Efficiency	22.8%	22.8%	23.0%	23.3%	23.1%	23.2%
Module Size (mm)	1722×1134×30	2278×1134×30	1762×1134×30	2382×1134×30	2172*1303*33	2384*1303*33

Table 1. TOPCon Modules

2.1.Elevating Quality Through In-House Material Manufacturing Capabilities

CSI Solar’s self-produced N-type silicon ingots and wafers have an oxygen content controlled within 10-11 ppma and minority carrier lifetime controlled to above 6000 μs, ensuring the efficiency and reliability of TOPCon modules.

CSI Solar's self-produced TOPCon cells have overcome the relatively challenging PECVD route, demonstrating significant advantages in mass production. Through in-depth research and practice, technical issues related to the PECVD process have been successfully resolved. The yield of Canadian Solar’s TOPCon cells has reached over 98%, with cell efficiency exceeding 26.5%.

CSI Solar's self-produced TOPCon modules use an intelligent module design software system to comprehensively evaluate the diversity of module installations and the compatibility with mounting brackets. Additionally, CSI Solar's TOPCon modules have undergone rigorous testing, with the power degradation of the modules after such tests being far below the IEC requirements.

2.2.Enhanced Power Output in High-Temperature Environments

The operating temperature of modules significantly influences their power output. CSI TOPCon modules utilize N-type silicon wafers with extended minority carrier lifetimes, coupled with the implementation of advanced tunnel oxide passivating contacts technology. This approach involves enhancing the cell's open-circuit voltage (Voc) through the deposition of an ultra-thin oxide layer and the doping of a polysilicon layer on the cell's rear, thereby facilitating effective interface passivation. The resulting higher open-circuit voltage contributes to a more favorable module temperature coefficient.

As a result, CSI TOPCon modules performs better than PERC modules when operating in high temperature environments (Figure 2).

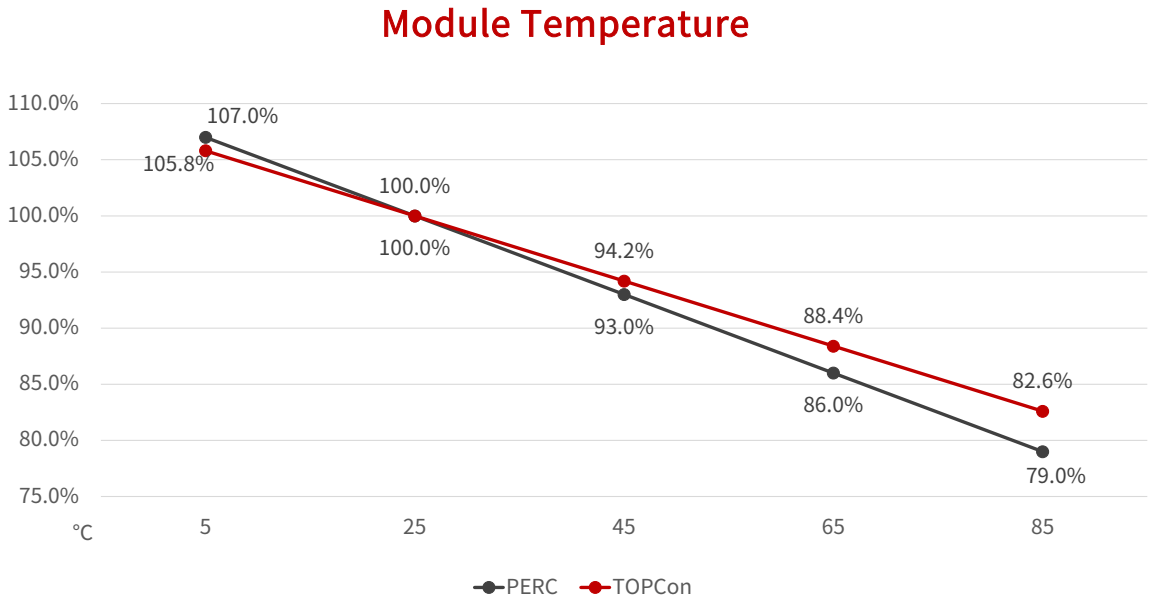


Figure 2. Influence of module temperature on its power output

2.3.Better Performance and Reliability

CSI Solar has embraced an industry-leading firing technology in the manufacturing of TOPCon cells. This technique effectively reduces the contact resistance between the metal and the semiconductor, thereby increasing the Fill Factor (FF). Additionally, it enables the achievement of passivation recovery effects, resulting in a significant enhancement of the cell's open-circuit voltage(Voc). Mass production verification has demonstrated that the integration of advanced firing technology with designated paste can elevate cell efficiency by 0.55%. This improvement includes an increase in Voc by 13.5mV and FF by 0.22% (Figure 3).

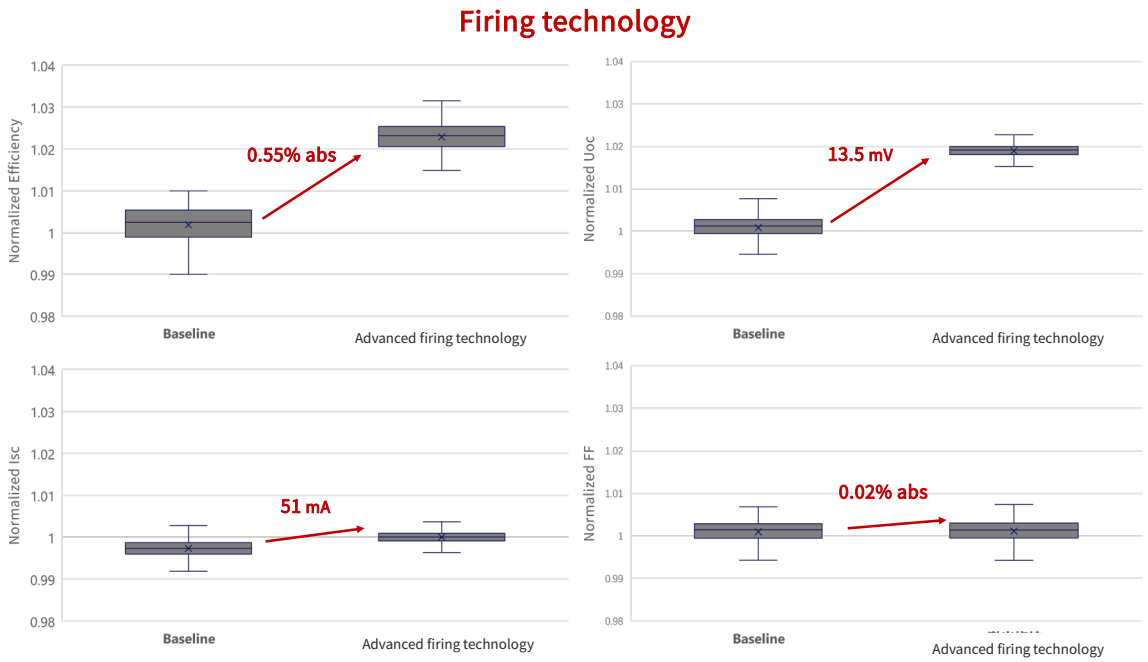


Figure 3. Industry-leading firing technology improves TOPCon cell performance

In the cell design, narrower and more numerous finger grid lines are implemented. This minimizes transmission distances, resulting in reduced shading areas and effectively lowering series resistance and silver paste consumption. Through simulation and experimental validation, it has been determined that 16 busbars (16BB) represent the optimal configuration for maximizing module power output for 182 Pro TOPCon modules.

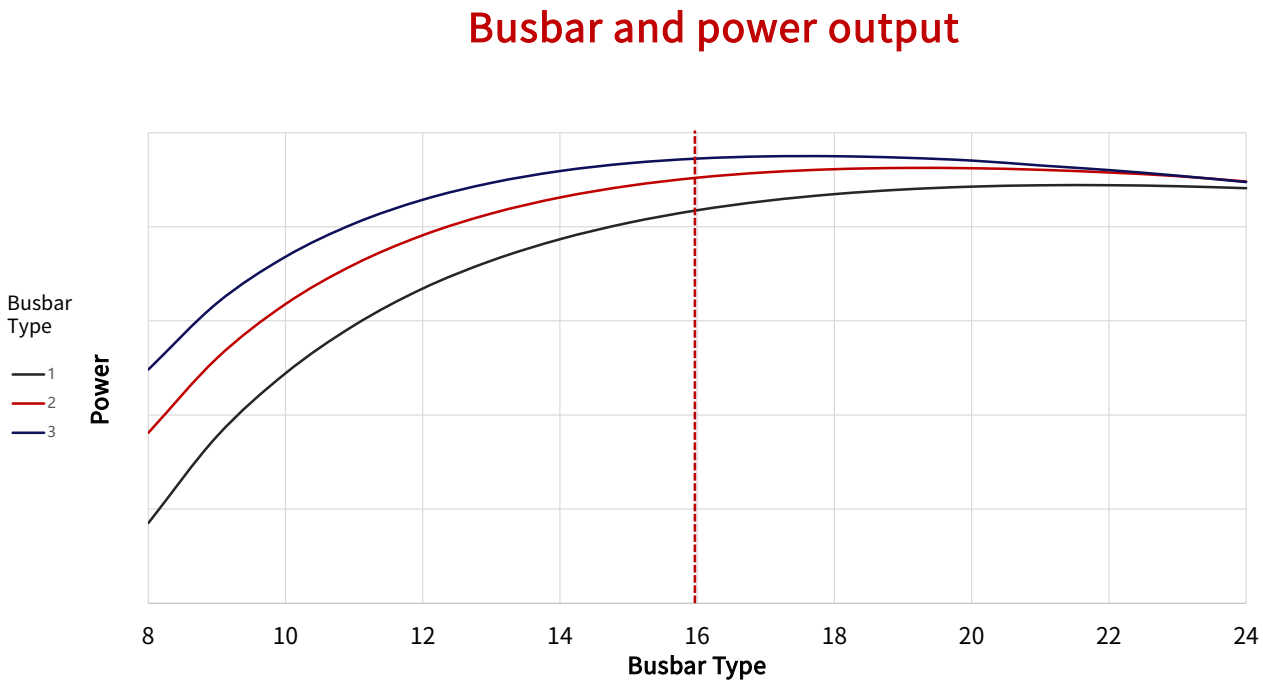


Figure 4. Relationship between number of busbar and power output

TOPCon cell is developed a symmetrical design on cell's front and back sides allows to make less shading area compared to PERC. With multiple bifaciality increase technologies on both cell and module levels combined, CSI TOPCon modules can see bifaciality of up to 85%.

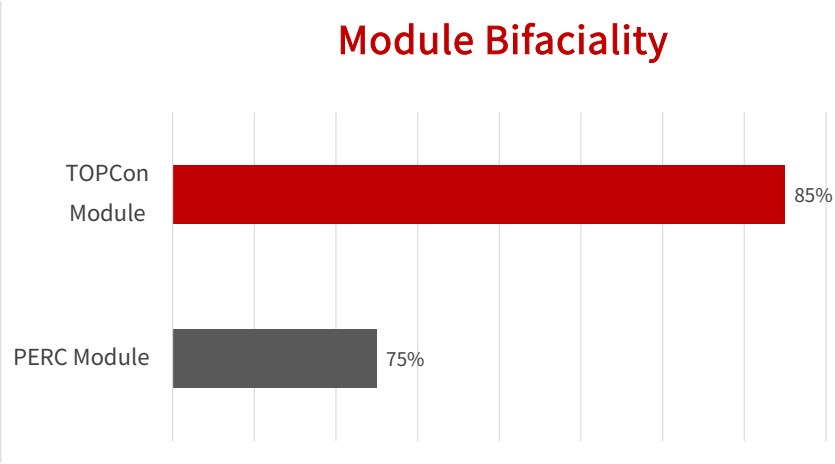


Figure 5. Bifaciality of PERC and TOPCon modules

Moreover, the CSI TOPCon module has been crafted with a focus on reliable product design and manufacturing technologies. This includes advanced processes such as non-destructive cell dicing, precise soldering (Figure 6), and high-density stringing technology. These features ensure the performance and reliability of the modules.

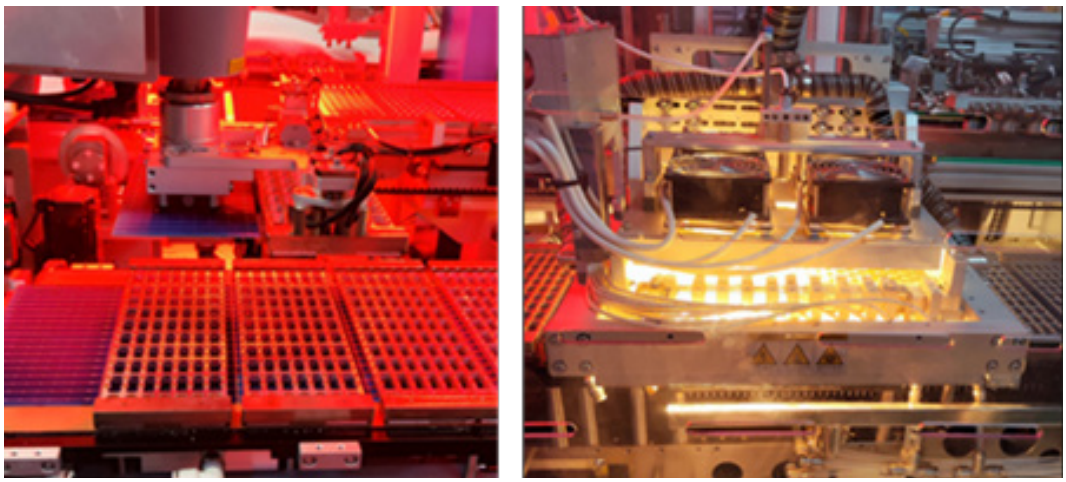


Figure 6. Non-destructive cell dicing and precise soldering for TOPCon modules

2.4.Industry Leading Extended Reliability Testing

CSI Solar has established in-house reliability testing protocol with testing doses of 2 times and even 3 times of IEC standard to ensure great product reliability (Table 2).

Tests	IEC 61730/61215	CSI Extended Reliability Testing
DH	1000 hours	2000~3000 hours
TC	200 cycles	400~600 cycles
HF	10 cycles	20~30 cycles
PID	96 hours	192 hours

Figure 6. Non-destructive cell dicing and precise soldering for TOPCon modules

Our test results show that TOPCon modules performed better compared to PERC modules.

Taking Damp Heat (DH) for example, TOPCon bifacial modules showed less than 1% power degradation after DH2000 testing, which was much lower than 5% required by IEC standard after DH1000.

CSI Solar optimized cells' UV resistance through proper light injection together with annealing and anti-reflection design. CSI Solar also developed a cell-level UV assessment method for daily monitoring. After UV irradiation of 60kWh/m^2, TOPCon cells showed about 0.2% less degradation compared to PERC cells (Figure 7).

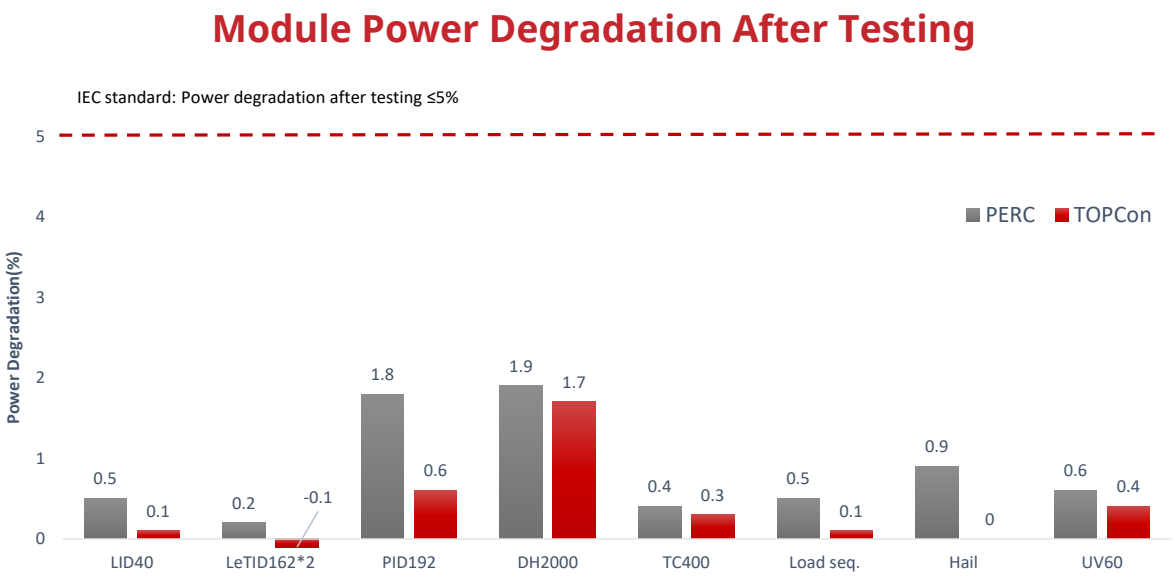


Figure 7. Reliability test results of PERC and TOPCon modules

2.5.Longer Warranty, Lower Power Degradation

Symmetrical design on the front and back sides of TOPCon cells reduces internal stress and enhances module resistance under temperature changes. Furthermore, higher minority carrier lifetime and no boron-oxygen related degradation bring TOPCon modules lower degradation rate. In addition, high quality encapsulation and advanced module manufacturing technologies further enhance TOPCon modules' performance.

CSI Solar offers 30-year power warranty for TOPCon modules and guarantees power degradation less than 1% in the first year and less than 0.4% per year thereafter. Longer module warranty and lower power degradation significantly increase power output in modules' lifetime (Figure 8).

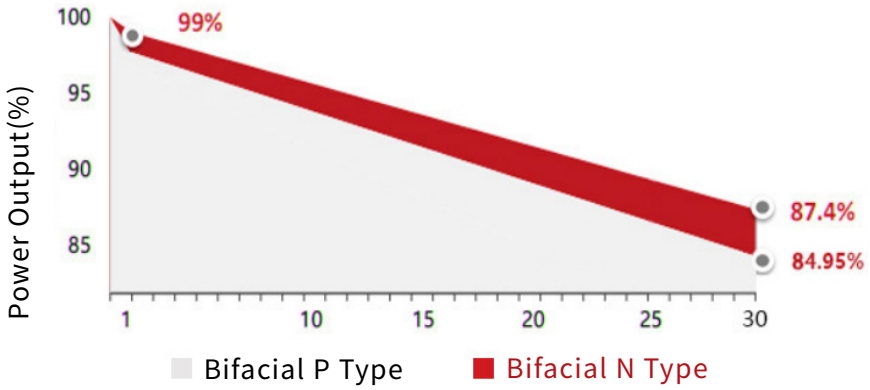


Figure 8. Lifetime power output of TOPCon and PERC modules

3.CSI 182 Pro TOPCon Module: Lower Shipping cost, Higher System Compatibility

3.1. Container utilization rate up to 99.8%, lower shipping costs

CSI 182 Pro TOPCon module is based on a rectangular wafer design, tapping the potential of the module in the length direction. It improves both module power and container utilization rate at the same time.

For overseas shipping, using a standard 40-foot high-cube container as an example, 182 TOPCon can be loaded with 413 kW, while 182 Pro TOPCon can be loaded with 446 kW, representing an increase of about 8.0%.

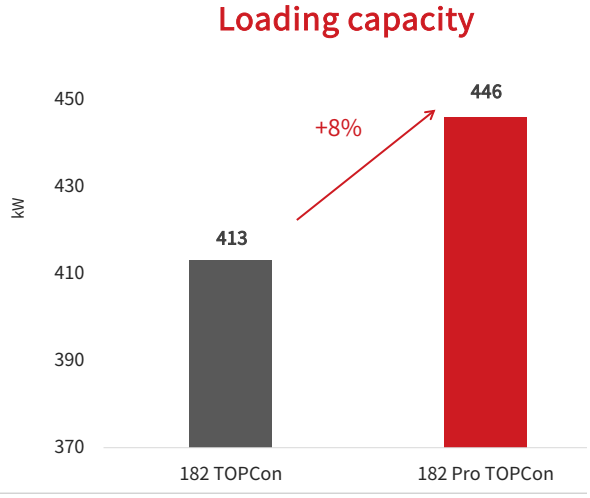


Figure 9. Loading capacity comparison between 182 TOPCon and 182 Pro TOPCon

3.2.Stronger System Compatibility

182 Pro TOPCon modules are compatible with mainstream mounting systems, whether fixed mounting systems or trackers, such as Nextracker, Soltec, Array, Arctech Solar PVH and JSOLAR (Figure 10).

Figure 10. Mainstream rack manufacturers

CSI Solar cooperates with major inverter manufacturers to provide customers with complete string inverter solutions. Currently, 182 Pro TOPCon modules are compatible with well-known string inverter brands including: Sungrow, Ginlang, Huawei, etc (Figure 11). Compared with 182 TOPCon, 182 Pro modules working with 30A/MPPT string inverters can fully utilize the MPPT current, while inverter's over-matching loss is almost the same. With higher module power, 182 Pro TOPCon module can further improve the DC/AC ratio to lower LCOE, thus more profits can be achieved.

Figure 11. Mainstream inverter suppliers

4.CSI 182 Pro TOPCon Module: Lower BOS and LCOE

In order to understand TOPCon modules' performance compared to PERC modules,
CSI Solar simulated system performance between 182 TOPCon and 182 Pro TOPCon modules based on a 28.7MW solar project located in Germany.

Module Type	182 TOPCon Bifacial - 590W	182Pro TOPCon Bifacial - 620W
Power（W）	590	620
Module Area(m^2)	2.6	2.7
Module Efficiency	22.80%	23.00%
Module Open-Circuit Voltage(V)	52.6	48.4
Annual Degradation Rate	0.40%	0.40%
Location	Germany	
DC System Size (MWdc)	28.7	
DC/AC Ratio	1.3	
Project site area (m2)	The same area	
Installation Method	Tracker 1 P	
Service Life	30 year	
Ground Coverage Ratio	0.326	0.325
Pitch (m)	6.98	7.34
Module Number/String	26	28
String Number per table	3	3
Module Number per table	78	84
Module Power per rack (W)	46020	52080
Total Length per rack table (m)	88	95

Table 3. Parameters used in system performance

4.1.Lower BOS Cost

Due to higher power of 182 Pro TOPCon bifacial module, less modules will be required for similar DC capacity. Subsequently, other costs such as installation and racks, will also be reduced. The overall BOS cost of 182 Pro TOPCon bifacial module is expected to decrease by about 1.3% (Table 4).

Module Type	182 TOPCon Bifacial -590W	182 Pro TOPCon Bifacial - 620W
Module Installation Cost	Baseline	-0.13%
Rack Material Cost	Baseline	-0.85%
Rack Installation Cost	Baseline	-0.2%
Material and Installation Cost of Cable and Combiner Box	Baseline	-0.12%
Development Cost	Baseline	—
Total BOS Cost	**Baseline**	**-1.30%**

Table 4. Comparison of BOS cost between PERC and TOPCon modules

4.2.Lower LCOE

Based on above simulation, 182 Pro TOPCon has almost the same energy yield as 182 TOPCon in the 30 years lifetime, while the BOS cost of 182 Pro is lower. As the result, the LCOE of system using 182 TOPCon bifacial modules would be about 48.4$/MWh, while the LCOE of system using 182 Pro TOPCon bifacial modules would be about 48.1$/MWh, about 0.6% less (Figure 12).

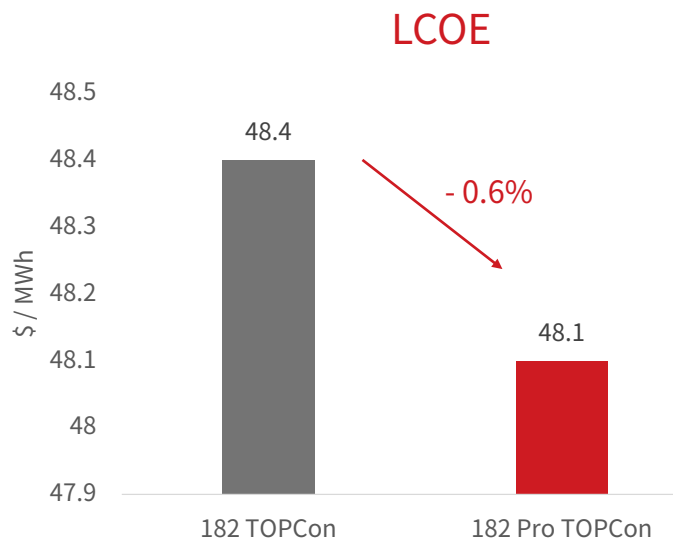


Figure12. LCOE comparison between systems with 182 TOPCon and 182 Pro TOPCon bifacial modules

4.3.Cover all application scenarios

Compared with 210 TOPCon modules are mainly used for large utility and C&I, CSI 182 Pro TOPCon can cover all application scenarios from residential, C&I to utility.

It can meet the needs of different customers in various conditions.

5.Summary

By 2024, the photovoltaic (PV) industry is poised for a comprehensive transition from P-type to N-type technology. Presently, several emerging technologies, notably TOPCon, HJT, and BC, have progressed to mass production stages. CSI Solar has R&D plans for all these cell and module technologies. CSI believes TOPCon is the most cost-effective technology right now. Notably, CSI Solar has achieved full production capacity of 30GW for TOPCon cells, boasting multiple industry-leading properties.

CSI Solar 182 Pro TOPCon modules adopt rectangular silicon wafers and cells, with a residential module current of approximately 10.8A, perfectly matching the main inverters, reducing inverter power redundancy and lowering the Balance of System (BOS) and levelized cost of electricity (LCOE) of the photovoltaic system.

The power of the 182 Pro 66-cell format module reaches up to 630 watts, with dimensions of 2,382mm x 1,134mm, effectively utilizing the space within shipping containers and reducing module transportation costs. The module width is the same as that of conventional 182 modules, facilitating handling and installation.
Compared to PERC modules, TOPCon modules exhibit superior attributes, including lower temperature coefficient and degradation, as well as higher bifaciality. Implementing solar systems utilizing CSI TOPCon modules can potentially reduce Balance of System (BOS) costs and levelized cost of electricity (LCOE) by nearly 1% over the 30-year performance warranty period.

CSI Solar’s 182 Pro TOPCon series modules are worth the anticipation. Welcome to click here and contact us for purchasing.

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