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ALL ABOUT SOLAR POWER

Iran Solar Magazine

Bifacial Solar Technology

2021 Edition – Part 1

Bifacial Cells & Modules

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Contents

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Executive Summary

Since our 2nd TaiyangNews Report Edition on Bifacial Module Technology was published in mid-2018, the technology has rapidly established itself as a mainstream product, reaching a low 2-digit market share both on the cell and module level. Such was the technological progress that we find it impractical to cover the topic in a single publication. Accordingly, we have split the 2021 edition of our Bifacial Solar Technology Report into two parts – Part 1 discusses the manufacturing side of the technology, essentially covering notable developments in cell and module manufacturing; Part 2, to be published very soon, delves into the application side, focusing on the different parts of bifacial solar systems.

After an introduction, Part 1 of the report provides an overview of the fundamentals and a brief history of bifacial technology. An important attribute of bifacial substrates is the so-called bifaciality factor, which is the ratio of the front side performance to the rear in standard test conditions, and the bifaciality coefficient, which is different for each cell technology. PERC, for example, has the lowest bifaciality of 65% to 75%, while heterojunction cells by far have the highest recorded bifaciality of up to 90%. Chapter 2 also briefly discusses developments associated with bifacial technology, especially in the areas of bankability and simulation.

While upstream manufacturing of bifacial PV remains the same as for monofacial solar, the cell level is where it's changing. P-type PERC, heterojunction (HJT) and the relatively new TOPCon architectures are most suitable for going bifacial. With a little tweaking, even the highest crystalline silicon efficiency cell structure, IBC presents itself as an eligible candidate to produce power on both cell sides. Chapter 3 discusses and assesses various aspects of processing different bifacial cell technologies, while displaying the top efficiencies announced by the leading players in this field.

Bifacial technology requires some changes at the module level as well. Chapter 4 elaborates on bifacial-specific changes and recent developments related to interconnection and module BOM, such as glass, frames, transparent backsheets and encapsulation materials.

Characterization of bifacial PV substrates remains a bone of contention. In Chapter 5, we discuss the IEC's recently released technical specification (TS) 60904-1-2:2019 with two proposed methods of measuring IV characteristics of bifacial PV. One way is to have two separate light sources for each side of the PV substrate, which seems to be favored by most manufacturers and tool suppliers. The other, advocated by the IEC, is to accomplish the measurement on the front side alone; here, the rear power is calculated based on the bifaciality factor.

With increased traction in mainstream commercial production, bifacial has also started to figure prominently in the product portfolio of leading module makers. When analyzing the datasheets of module products from leading suppliers, more and more products are made by combining several advanced technologies into one product – and bifacial has become an important ingredient of advanced modules. A very more prominent development is employing larger cells in pursuit of higher module power. When analyzing the module products of leading suppliers, the most important attribute of a module, which is power, is now mainly a function of wafer size rather than the technology on which it is built. Thus, we have grouped the bifacial module products from leading companies according to the 4 mainstream wafer sizes – G12, M10, M6 and G1. The product characteristics from selected module producers are discussed in detail in Chapter 6.

As of today, PERC, with its large and clearly dominating production capacity, is also the most cost-effective bifacial technology. Shifting from monofacial PERC to bifacial is not cost-additive, and the switch can be done rather spontaneously, depending on demand. What it requires in terms of hardware is a high precision printer for applying the aluminum grid – and the majority of the latest cell lines include such a printer. Moreover, every advanced cell technology beyond PERC is inherently bifacial. The increased adoption of bifacial in mainstream production is also reflected in its quickly growing market share, which ITRPV anticipates reaching 70% on the cell level and 35% on the module level by 2030, as described in Chapter 7.

The report also features an interview with a longtime supporter of bifacial technology LONGi Solar, which has been carrying forward the legacy of bifacial technology through several product generations, including the latest HiMO5.

Enjoy reading our Bifacial Solar Technology 2021 Edition - Part 1

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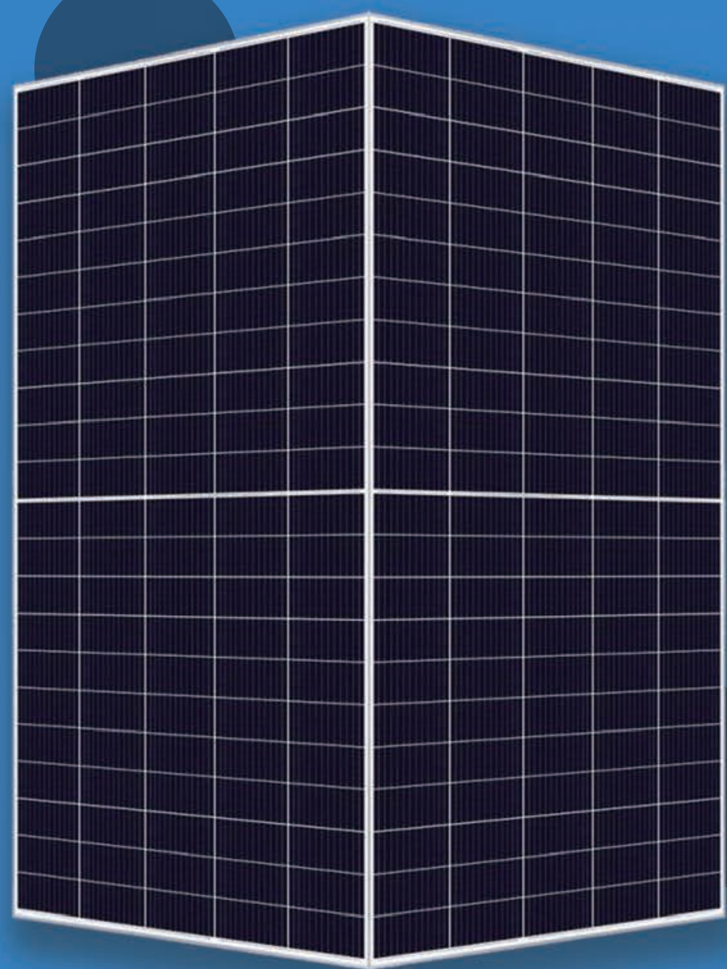
Bifacial PV Module



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1. Introduction

It's astonishing how things change when they're least expected. Case in point – bifacial PV technology. For more than a decade, the use of bifacial PV was largely limited to prototype and proof of concept projects, such as sound barriers in highways and railways, east-west installations to shave the noon peaks and some building-integrated applications, other than being a subject of interest for research.

But that is history, and bifacial PV technology really seems to have turned the corner. Bifacial solar is now increasingly becoming an interesting option for large scale PV systems too.

In fact, since we published the 2nd Edition of our TaiyangNews Report on Bifacial Module Technology in mid-2018, the technology has made tremendous progress. As with any new technology, bifacial PV has had its share of growing pains. For example, as we reported in our 2018 report, a 300 MW solar tender did not consider a bifacial bid despite it being the lowest at 1.79 US cents per kWh of PV power generation. Why? Because the technology was simply not bankable back then as there was no performance data from larger PV systems. However, it was just a matter of time that the technology made its presence felt. Things have changed dramatically since the end of 2018. During this time, several companies have announced bifacial projects backed by financial institutions around the world.

In 2019, the US government exempted the duties on bifacial modules. The exception took several twists and turns and currently come under the tariff regime. The IEC standard to measure and label bifacial PV devices is available from the beginning of 2019. Though it is a "TS" standard, it is a step forward towards the standardization, lack of which has been a major hurdle for the manufacturers.

As readers might know, PVsyst is a simulation software often relied upon by financial institutions for estimating the power output of an installed PV system in a specific area. And with the developments in this area over time, PVsyst has added the bifacial function to its simulation suite.

Source: LONGi

Rapid development: A few years ago, bifacial solar technology was only serving niche applications, now it is an important part of many mainstream large-scale installations.

Leading research institutes have also followed suit and are developing simulation tools to estimate the bifacial system's power output more precisely.

There has also been remarkable progress in bifacial manufacturing at the cell and module levels. Even PERC, which is not bifacial and has now become a mainstream technology in mass production, can be made bifacial with little effort. TaiyangNews learned that a leading cell maker sold the bifacial variant of PERC cells at a marginally lower price than monofacial cells at one point in time. This is proof that cell manufacturers have mastered the art of making bifacial PERC cells effortlessly without increasing manufacturing costs. Advanced cell technologies such as heterojunction and passivated contacts with high bifaciality are also entering high-volume manufacturing, which is further pushing bifacial's image in the global PV technology mix. Not just at the cell level, bifacial is also compatible and complements several advanced module technologies such as half cell, MBB, shingling, Tiling Ribbon and so on. As a matter of fact, several module makers have started offering bifacial modules combined with other advanced module technologies (see TaiyangNews Advanced Module Technology 2021 Report).

To put it simply, bifacial's progress as a technology has been quite impressive in manufacturing, application and in each of their subsections since we published our second edition. It may not be practical to dig deeper into all of the interesting developments associated with the technology in one single report. As such, we have split the 2021 edition of our Bifacial PV Technology report into two parts. Part 1, the one you're reading now, discusses the manufacturing side of the technology, essentially covering important developments in cell and module manufacturing with respect to bifacial. The second part of the report, which will also be released soon, delves into the application side with a focus on systems technology.

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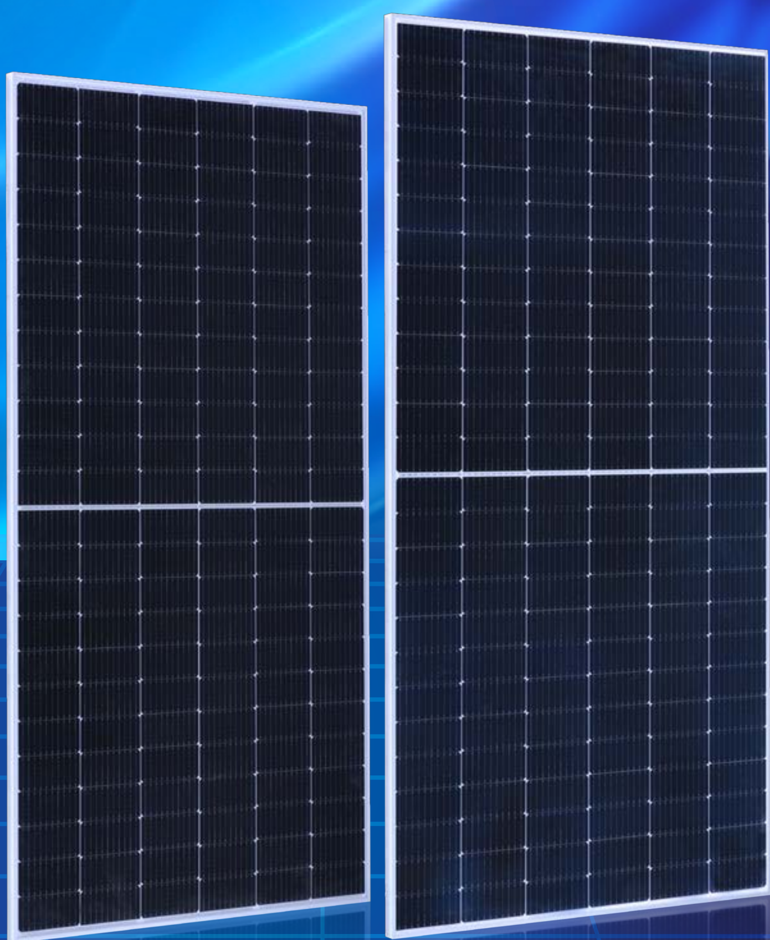

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2. Overview

Bifacial solar cell technology has been in existence for many decades. But like with any new technology, it had to go through a certain incubation period before the innovations could be adopted into mass production at a competitive cost. And it has finally arrived. Here are some basics of the bifacial technology, before we go into further details.

2.1 Basics of Bifacial Technology

For beginners, a typical PV panel has a front cover glass and an opaque polymer sheet. The latter is to cover the components of the module from the environment and reflected light. Why not open the rear of the PV module to absorb the reflected sunlight? After all, it is also made of silicon and, thus, sunlight sensitive. Well, that is what a bifacial PV device is. Bifacial PV is to make a PV substrate light sensitive on both sides in order to maximize sunlight absorption and ultimately improve the power yield. A typical bifacial PV cell is primarily about printing a rear metallization pattern that is similar to the sunny side. And the ability to absorb light is also extended at a module level by using a transparent rear cover replacing the opaque backsheet.

An important attribute of bifacial cells and modules is the so-called **bifaciality factor**, which is the ratio of the front side performance to the rear in standard test conditions. It should be noted here that the bifaciality coefficient is different for each cell technology. PERC, for example, has the lowest bifaciality ranging from 65% to 75%, while heterojunction cells by far have recorded the highest bifaciality of 90% to 95%.

At the system level, the power gain varies from 5% to 30% depending on several technical and geographical conditions. There are several ways to improve the yield of a bifacial solar installation. As the output of the rear side of the modules relies to a large extent on the site albedo (sunlight reflected by the ground), developers need to select installation sites with a natural high albedo or look at ways to reflect more light artificially. East-west installations are one option to avoid noon peaks, which is a limitation of traditional PV systems.

The good thing is that all these concepts are industrially feasible. An important attribute of the technology at a system level is the so-called **bifacial gain**, which according to the research group from the International Solar Energy Research Center (ISC) Konstanz is calculated using the following equation: Note: $G_{bifacial}$ is bifacial gain; $e_{bifacial}$ is specific energy

$$g_{bifcaial}(\%) = \left(\frac{(e_{bifcaial} - e_{monofcaial})}{e_{monofcaial}}\right) x\ 100$$

yield (kWh/kWp) of bifacial PV; $e_{monofacial}$ is specific energy yield (kWh/kWp) of standard PV.

The US National Renewable Energy Laboratory (NREL) provided an even more simplified expression to evaluate the bifacial gain. For performance modeling, the main advantage with a bifacial system is the additional rear irradiance contribution. The total bifacial irradiance consists of two factors – the front side radiance in addition to the rear contribution. As mentioned earlier, the bifaciality factor of every cell/module technology is different. Thus, not all of the rear irradiance contribution is considered at the same level as the front side. To calculate the rear irradiance (for a particular module technology), the measured rear irradiance is multiplied with bifaciality. The below formula simplifies the above explanation.

$$G_{Total} = G_{Front} + [(G_{Rear}) \text{ x } (\text{bifaciality})]$$

G_{Total}: Total bifacial irradiance; G_{Front}: front side measured irradiance; G_{Rear}: measured irradiance on rear side.

2.2 History of Bifacial Technology

The bifacial concept isn't new. Its history started as early as 1960 and is nicely summarized by Andrés Cuevas in a paper titled "The Early History of Bifacial Solar Cells," which he presented at the 20th European Photovoltaic Solar Energy Conference. Who invented the bifacial concept is still a subject of debate. Some publications give the credit to a group of Russian scientists, headed by A.K. Zaitseva and O.P. Fedoseeva.

At the same time, Japanese scientist H. Mori patented a similar bifacial structure, forming a p-n junction on both sides of an n-type silicon wafer that resulted in a p+np+ structure. Such a cell has emitters and contact grids on both sides, referred as triode cell.

Based on this triode structure, a research group led by Andrés Cuevas reported the first credible efficiency of 12.7% on a 4 cm^2 cell between 1979 and 1980. The above-mentioned technical paper summarizes how the development of bifacial technology has paved the path towards current cell structures. In fact, the first BSF cell fabricated by Ninel Bordin in 1970 was also a bifacial cell, processed without aluminum, but involving active diffusion. The other path of bifacial design – featuring dielectric passivation and resulting in n+p structure, which was reported in 1977 at the 1st EU PVSEC in Luxembourg (Silicon Double Solar Cell; Authors: I. Chambouleyron and Y. Chevalier) – has conceptual similarities to PERC architecture.

In those early days of PV, bifacial technology was mainly limited to space applications. In the terrestrial field, bifacial solar was mainly coupled with flat mirrors that directed sunlight towards the rear side, as it was proposed by the inventors of the technology. At the time, static concentrators were used to illuminate the rear side. It was only around 1980 that different groups of scientists realized the ability of bifacial modules to be sensitive to the natural albedo of the environment.

The year 2000 was the year of “revival” for bifacial technology. Japan’s Hitachi fabricated high-efficiency bifacial cells with efficiencies of 21.3% on the front and 19.8% on the rear based on the triode structure of the first bifacial cells. At almost the same time, Sanyo (now Panasonic) started commercializing bifacial modules based on its proprietary Heterojunction with Intrinsic Thin layer (HIT) design. With Germany starting its PV feed-in tariff program in 2000 and the beginning of the European solar era, researchers from the Continent jumped on the promising technology – ISC and the Energy Research Centre of the Netherlands (ECN) were developing approaches to leave the aluminum-BSF behind and passivate the rear side using standard production tools to keep costs close to standard cells. However, success was hard to come by, and it remained a niche as most of the followers of the technology were stuck at the proof of concept level.

Source: Suntech

Technology for all: While bifacial was mainly considered for installation sites with high albedo in the past, technology developments have reduced its costs to the level of monofacial cells, now enabling bifacial modules to be compatible for a variety of applications and locations.

2.3 Important Developments

Three topics always find themselves at the center of discussion for any new technology to enter into the mainstream – bankability, standardization, and power measurement/solar simulation. And bifacial PV technology has made considerable progress in all these aspects in recent times.

Bankability is nothing but the likelihood of financial institutions providing financing for a project featuring a particular technology. A major prerequisite for this is supporting data from a large system that has been running for a considerable time period, let's say for 2 to 5 years. Bankability is also tricky; something akin to a chicken and egg issue. On the one hand, it is difficult to build large systems without proper funding. And on the flip side, the banks won't approve grants unless large system data is available. Being a new technology, the situation is no different with bifacial. As a result, some of the early pioneers of the bifacial technology have suffered. Italy-based MegaCell is one example. The company was among the first to install larger bifacial power plants in La Hormiga, Chile in the scale of 2.5 MW. However, according to Radovan Kopecek, managing director of ISC Konstanz, the largest system data available at that time to procure financing for Megacell's systems was 1 MW installed in Japan, which for a technology like bifacial is already large, but for PV as a whole is nearly negligible. As a result, financial institutions did not fund Megacell's projects and the company filed for insolvency.

The first step towards building larger bifacial systems was facilitated by the Top Runner Program from the Chinese government, which has incentivized high-efficiency and high-power providing PV technologies. Bifacial, with its apparent ability to boost power yield, benefited considerably. Bifacial technology had more than a 50% share in the third phase of the program. Most of the larger bifacial solar farms built in China in recent years were under the Top Runner Program, which made bifacial technology indirectly bankable in China. The US government had exempted bifacial panels from the 30% tariff on imported solar panels through Section 201 in June 2019. This amendment to the trade policy took a roller coaster ride since then. It was interesting that the tariff was revoked in October, after a mere 4 months. The U.S. Court of International Trade (CIT) issued a temporary restraining order on the revocation in November, and subsequently the Court decided to continue the exemption indefinitely in December.


Source: ISC Konstanz

Finally, bankable: While there is no more discussion about the bankability of bifacial modules today, the early pioneers of the technology faced a different climate. MegaCell, which was among the first to install large bifacial power plants, like the La Hormiga plant in Chile, suffered from lacking bankability of bifacial modules at the time. The company had to file for insolvency.

However, in April 2020, the bifacial technology was once again brought under section 201, and again in October, the bifacial PV escaped the tariff regime as a US court issued a temporary restraining order. Finally, in November 2020, the US Court of International Trade ruled in favor of bringing imported bifacial solar modules under tariff regime of Section 201. This entire exercise has certainly acted as a catalyst, triggering further interest in bifacial technology in the US with its very large utility-scale solar market segment. The learnings from these developments have further aided the understanding of the technology and the potential benefit it brings, furthering the bankability argument for bifacial across the globe.

Currently, bankability is not even a topic as projects around the world are completely funded by banks and financial institutions. While it's difficult to point out the first completely bankable bifacial installation, Scatec's project in Egypt is one and its size of 400 MW has definitely become a reference point. This project was to be executed in 6 sections. And in April 2019, Scatec Solar announced that its first batch of 65 MW went online in Egypt's Benban solar complex. The project was financed by The European Bank for Reconstruction and Development (EBRD). Actually, the agreement for the project financing was signed in April 2017, while module technology was not specified back then.

In January 2019, US-based Invenergy announced that it completed construction financing in December 2018 for its 224 MW (DC) Southern Oak Solar project, located in Mitchell County, Georgia. This is the solar park built with bifacial modules and single-axis tracking using products from LONGi and NEXTracker, respectively. CoBank acted as the sole lender, issuing bank, collateral agent and administrative agent for the deal, according to a press release from the company. Following these leads, several companies announced funding of bifacial PV projects by financial institutes around the world. Bifacial PV not only became bankable, but has also been able to reduce the LCOE. ACWA Power from Saudi Arabia won a bid in August 2019 with an electricity price offer of 2.752 US cents per kWh by betting on bifacial technology. In summary, bifacial technology has become bankable since our last report in 2018 and, as such, is also an increasingly interesting choice for investors.


Source: Novus Green

One more glass loader, please: From a manufacturing point of view, bifacial module lines need an extra glass loader, which is now part of most of the new solar panel fabs, as is the case with India's Novus Green.

Simulation is one of the key facilitators for improved bankability of bifacial technology. As mentioned above, PVsyst has added the bifacial function to its software suite. PVsyst is now able to quantify the benefit of a bifacial system in both fixed tilt as well as installations with trackers. However, according to most experts in the industry we spoke to, the simulation results from PVsyst are still rather 'conservative.' That means the bifacial gain of a PV system estimated with the software, especially with trackers, is less compared to what can be extracted in real time. ISC's Kopecek gave an example of a horizontal single-axis tracker. When combined with a bifacial system, PVsyst shows a gain of 4%, which is less than half of what's been observed from experimental/real-time data, showing up to 10% gain. However, even with the nominal 4% gain showed by PVsyst, installers are increasingly showing interest in bifacial. Module makers, while often not actively selling the bifacial function of their products, meaning there is no per watt sales metric for bifacial gain, thus are charging only a fixed premium for bifacial modules over the monofacial products. Cost-wise, the major change required for making a bifacial module is the switch to a glass-glass configuration – an approach many module manufacturers have been evaluating anyway for utility-scale products, with an eye towards the possibility of extending the power warranty from 25 to 30 years.

However, research centers and large companies have been developing software solutions to map the power gain of bifacial systems more accurately. "It is quite a nice opportunity for the institutions also to cooperate with big companies to double check the PVsyst simulations," said Kopecek. On the other hand, NREL has developed a tool called SAM, ECN calls its program as BIGEYE, and MoBiDiG is the name of the bifacial modeling tool from ISC. Simulation models are getting better with more and more bifacial systems coming online and with an increasing amount of real-time data becoming available (details on simulation software will be published in part 2 of this report).

When the new IEC standard to measure the IV characteristics of bifacial PV devices (IEC TS 60904-1-2:2019) came into effect in 2019, another ambiguity about how to test and rate bifacial products had been addressed. Cell testers and sun simulators from leading suppliers are also now available to test bifacial PV devices. More details of characterization of bifacial substrates are discussed in Chapter 5 of this report.

Bifacial manufacturing is not complex anymore. At the cell level, the effort to tweak PERC to bifacial is negligible, as we explain in Chapter 3.1. In consequence, every solar cell maker involved in PERC has basically adapted the technology to bifacial. Concepts like increasing the number of busbars and multi-busbars reduce the criticality of rear metallization resistivity, also favor bifacial PERC. This approach compensates for the low conductivity originating from aluminum, which forms the rear contact. While n-type wafers are still more expensive, the bifacial gain is much higher than for p-type PERC, which is why companies are starting to look into n-type bifacial technology as well. All advanced cell architectures are naturally bifacial. Another advantage of this technology is its complementary nature – not only is it compatible with advanced module technologies such as MBB, half cell, shingling, tiled ribbon, but the benefits also add up. All this boils down to the fact that making bifacial does not meaningfully escalate costs.

These developments among the different parts of the PV value chain are directly or indirectly supporting the move to bifacial.

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3. Bifacial Cell Technology

Bifacial PV is a technology that requires specific changes in three stages of the PV value chain – cells, modules, and systems. As mentioned earlier, the system level information is dealt with in a separate edition of the report, while this chapter summarizes the changes and developments related to bifacial cells.

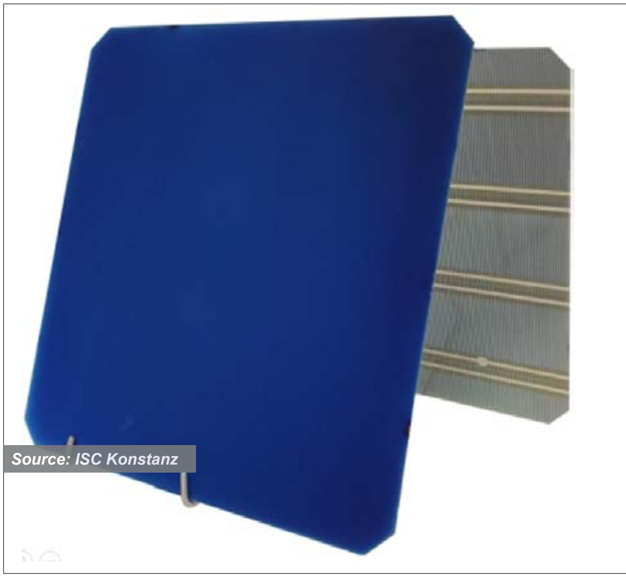
The cell level is obviously where it all starts to change for making bifacial PV. The choice is wide, because any move away from standard BSF technology to any of the advanced cell technologies qualifies for bifacial. One can pick from the three main commercial cell architectures – p-type PERC, the mainstream, and high efficiency cell types based on n-type wafers such as heterojunction (HJT), and the relatively new passivated contacts cell architecture, commonly called TOPCon. With some optimization, even the IBC cell structure is an eligible candidate for bifacial solar.

However, each of these cell architectures exhibits a different degree of bifaciality. HJT is the most effective, showing a bifaciality of above 90%, followed by the n-PERT architecture with a bifaciality of up to 90%. However, the ever-increasing production capacities of PERC are creating a wide knowledge pool for the technology that is helping achieve greater efficiencies than the common n-type PERx level. As a result, n-PERx followers are forced to look beyond their technologies.

TOPCon is one promising technology in this regard. Almost every follower of n-PERx technology has already upgraded or is in the process of upgrading to TOPCon. When it comes to bifaciality of TOPCon cell architecture, it suffers from slightly lower bifaciality of about 80%. The IBC cell structure, bearing the contacts of both polarities on the rear side, can also be tweaked to be bifacial. The ZEBRA structure from ISC Konstanz results in a bifaciality of about 70%. PERC scores the lowest with bifaciality of 65% to 75%.

3.1 p-PERC

PERC has established itself as the new standard in solar cell technology. It's good news for bifacial as well, as it is very easy to upgrade PERC to bifacial technology. PERC's bifacial capability is perhaps one important feature that has also helped the technology to spread wider and reign longer than many anticipated.

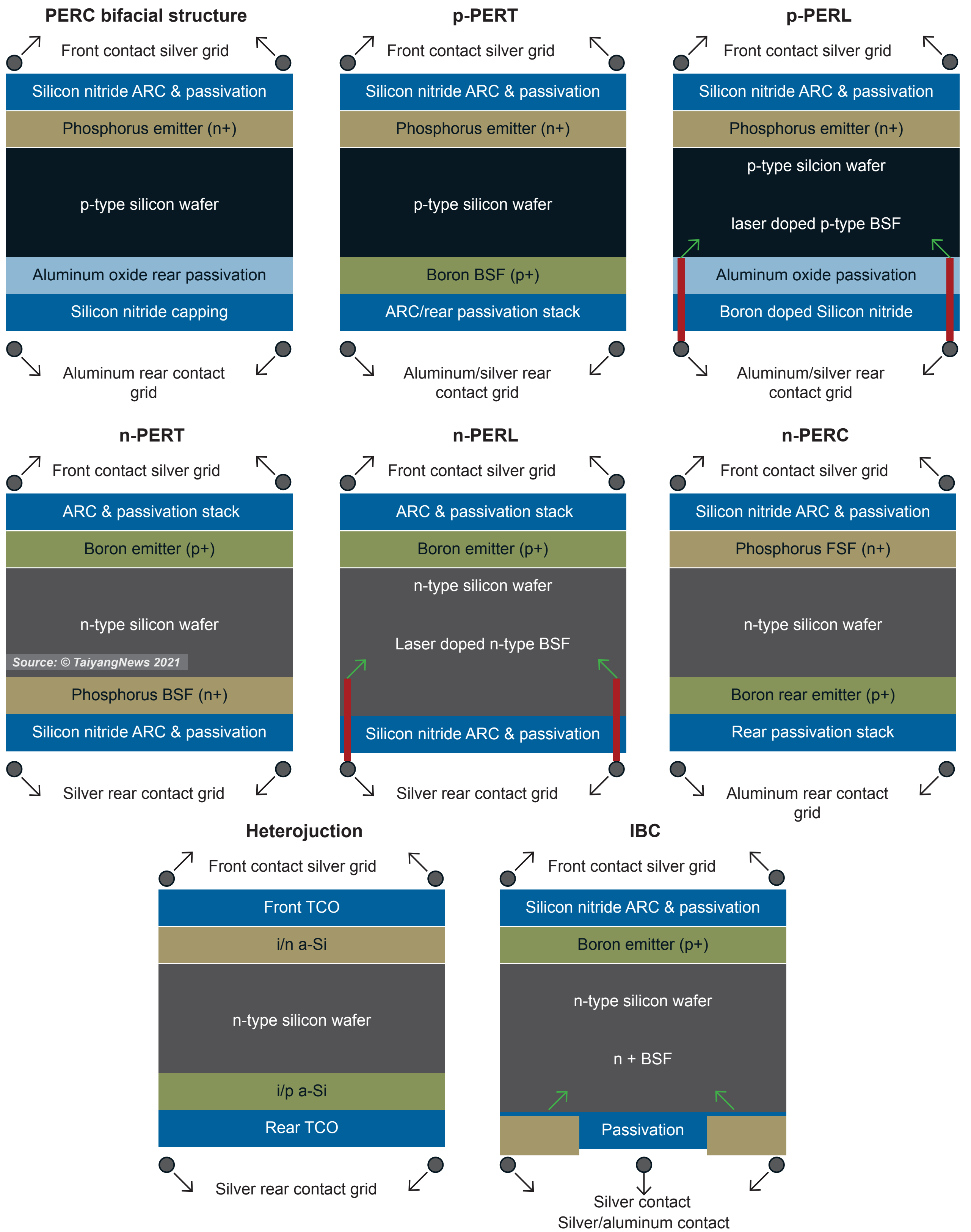

Source: ISC Konstanz

Back contact cells – high efficiency & bifacial: IBC is the efficiency leader among commercial silicon solar cell technologies. And it can be also tweaked to be bifacial, as shown by research institute ISC Konstanz, which sells licenses of its technology under the name of ZEBRA.

PERC is now so well established that it may not be necessary to discuss its basics. TaiyangNews has published three exclusive reports on PERC – in 2016, 2017 and 2018, which can be downloaded for free on our website.

PERC is the most simple and cost-effective candidate for bifacial. But unlike other advanced cell structures, PERC is not bifacial by default. That's because the standard PERC cell structure contains an opaque local BSF-forming layer of aluminum paste on the rear side. However, the step to turn PERC into a bifacial solar cell is rather simple, i.e., apply an aluminum grid instead of spreading paste over the full area. This requires specific aluminum pastes designed for printing fingers rather than the products used for full area prints. Now, there are several paste makers that are offering aluminum pastes that can support bifacial PERC.

Bifacial Solar Cell Architectures



Everyone's bifacial: Except for BSF cells, every solar cell technology in commercial production is bifacial by nature. The bifaciality rate differs between 65% and 90%.

Japan's Toyo Aluminium (Toyal) was the first paste maker to offer such products and is also the technology leader of the segment. Another advantage of this approach is that it avoids the usage of silver on the rear side, while most of the other bifacial structures need silver on both sides. Shifting from PERC to bifacial also requires some optimization in the areas of silicon nitride capping layer of the rear passivation stack and laser opening of the rear passivation layers.

The Institute for Solar Energy Research in Hamelin (ISFH) was among the first to evaluate bifacial PERC technology and presented its early results in a technical paper at EU PVSEC in 2015 (The PERC+ Cell: A 21%-Efficient Industrial Bifacial PERC Solar Cell, Authors: T. Dullweber et al.). The major area of optimization for the PERC bifacial structure is the rear aluminum grid. The early PERC bifacial cells suffered from low rear efficiencies, mainly due to employing fingers formed with a paste of aluminum, which has a lower conductivity compared to silver. Thus, relatively wider fingers are printed to achieve reasonable conductivity. This causes shading of 30% to 40% on the rear side, which in turn results in higher losses. But this is changing with improved aluminum pastes that are increasingly hitting the market.

And indeed, aluminum pastes have made huge strides in this area. During the inception days of PERC bifacial, the aluminum finger width was about 200 µm. According to Marwan Dhamrin, senior specialist and executive officer at Toyo, the current generation of pastes from his company can support finger widths as narrow as 60 µm. However, the current practice in the industry is to print through a 100 µm screen opening that results in finger widths of 120 to 160 µm. This is mainly to compensate any skew in the laser opening of the rear passivation layer. The pastes are continuously improving and soon aluminum finger widths would not be much higher than silver-based front metallization pattern, said Dhamrin. Narrowing the aluminum fingers reduces shadowing, thus improving bifaciality.

On the other hand, aluminum finger width reduction is not always good news. Going to thinner fingers increases resistance as aluminum's specific resistivity is quite high at about 6 times that of silver. For that reason, cell manufacturers have to be careful when reducing finger width. What could be interesting in this context is combining the bifacial PERC concept with a multi-busbar design. Multi-busbars help in reducing aluminum finger lengths, which limits the impact of grid lines in increasing resistance. In other words, multi-busbars enable printing of very narrow fingers without getting into series resistance issues.

Nearly every PV manufacturer active in the PERC field is also offering bifacial products, because bifaciality is a 'free' bonus for any PERC product and the benefit is passed onto the customers. This is also reflected in the latest price of quote from Tongwei. The China based leading cell supplier does not charge any price premium for bifacial cells over its monofacial products (see screen shot of quote). The company is offering three variants of bifacial cells, which differ in wafer size – G1, M6 and G12 –, so is the price 0.91 ¥/W, 0.95 ¥/W and 0.99 ¥/W, respectively. All these cells exhibit the same rear efficiency of 16%, while the front efficiency differs. According to the datasheets available on Tongwei's website, the M6 cell in 9-busbar configuration has a front efficiency of 22.9%, whereas the G1 cell also featuring 9-busbars is rated with a top efficiency of 22.6%.

The Pricing Announcement of Solar Cells of TW Solar in February, 2021

2021-01-26

The Pricing Announcement of Solar Cells of TW Solar in February, 2021

2021-1-26

The following are quotations of mainstream high-efficiency poly and mono cells.

Products	Type	Price (per Watt)
Poly Cell	Diamond wire 157	0.62
Mono PERC Cell	158.75 (including bifacial)	0.91
	166 (including bifacial)	0.95
	210 (including bifacial)	0.99

Source: Tongwei

No price premium for bifacial cells: Making bifacial cells basically doesn't add to production costs, which is also evident from the recent price quotes (February 21, 2021) from Tongwei, which sells the bifacial variants of its cell models for the same price as its monofacial products.

However, Tongwei had not updated its product list with data sheets of G12 cells by the time of our editorial deadline.

Aiko, Tongwei's close competitor from China, is offering 8 different commercial cell variants, of which 5 are only available in bifacial configuration, 2 supplied as both monofacial and bifacial variants and one model comes as only monofacial. The first line of difference between these products is wafer size – G12, M10, M6, M4 and M2. The cells using 210 mm full square wafers have two variants, both of which are only bifacial but differ in the number of busbars – either 12 or 9. The same differentiation is also applicable for the 2 cell models based on M6 wafer size. The G1 cells also follow the same classification, but the choice between the number of busbars is between 9 and 5. And each of the G1 variants is supplied in both monofacial and bifacial configuration.

Bifacial PERC

Technology characteristics: PERC is not intrinsically bifacial, but can be realized with simple optimization

	Topics	Status	Comments
Process	Influence on process sequence	✓	The rear aluminum local BSF is replaced with aluminum grid
	Additional process tools required	✗	All cell processing sequences remain the same, except for printer with high alignment accuracy also for rear
	Influence on passivation configuration	✗	No change required
	Influence on metallization	✓	Rear metallization requires optimization; requires special aluminum pastes to be applied in grid format; require sophisticated printer to align aluminum contacts to laser opening of rear passivation stack
Production	Status of commercialization	✓✓✓	Nearly every company involved in PERC is working on bifacial technology, if not already offering products
	Availability of production equipment	✓✓✓	Only special equipment required for biacial is advanced printer for aluminum, which is offered by many printing tool suppliers.
	Additional costs	✓✓✓	Bifaciality with PERC is bonus with bascially no additional costs
Performance	Challenges	✓✓	Low bifaciality due to wider aluminum fingers, which also exhibit high resistance
	Highest cell efficiency in production	>23%	Several companies have announced efficiencies above 23%
	Bifaciality	65% - 75%	The average bifaciality offered by several leading cell makers is 70 ± 5%
	Top commercial bifacial solar module power	655	Many module producers are adapting PERC technology on larger wafers; CSI is offering a 655 W module built with 66 equivalent 210 mm cells.

Note: The comparisons are referred to PERC as base line wherever applicable.
Legend: ✓ Low negative impact; ✓ Medium negative impact; ✓✓✓ High negative impact; ✓ Source: © TaiyangNews 2021
✓✓ Medium Positive impact; ✓✓✓ High positive impact; ✗ No impact;

Little effort: PERC is the simplest and most cost-effective bifacial solution available today. While not naturally bifacial, it requires little effort to unleash the bifacial bonus.

The M10, is yet another cell size that exclusively comes in bifacial only, while the M4 is available only in monofacial configuration. All variants had the same efficiency of 22.5% at the end of last year.

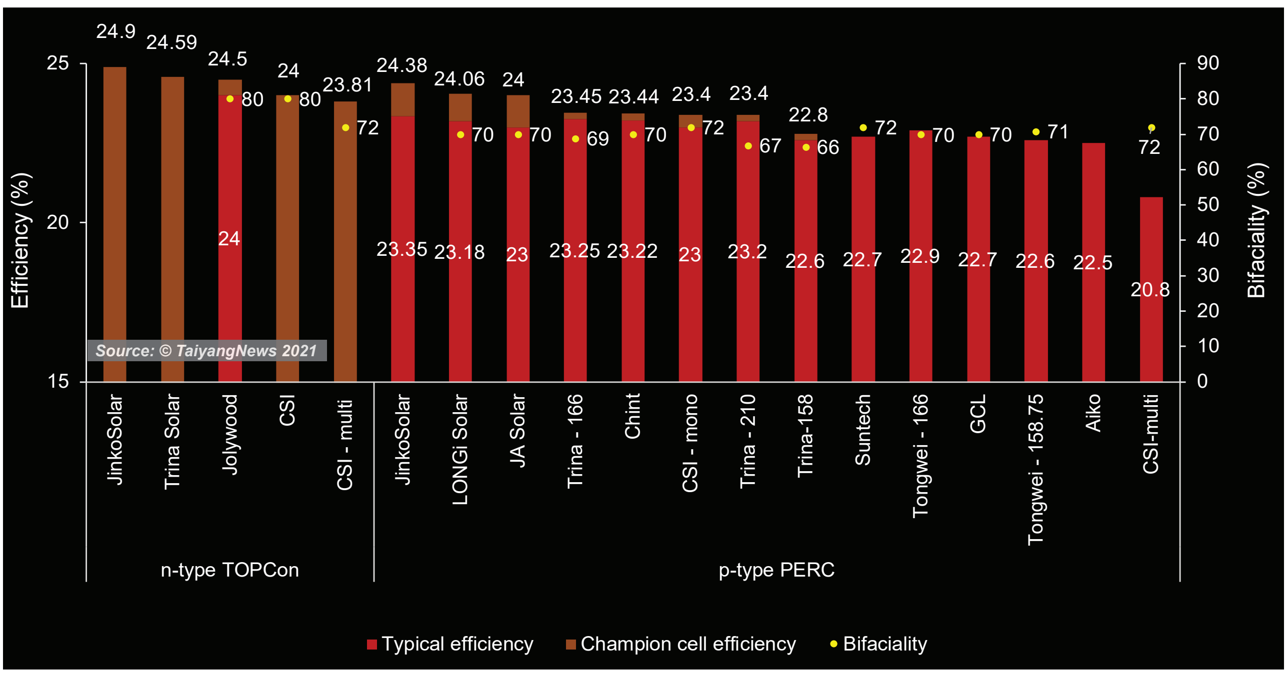
Unlike Aiko and Tongwei, which are mainly cell manufacturers, other leading PV companies that are fully integrated such as LONGi and JinkoSolar do not supply cells directly. However, a few companies have provided the efficiencies and bifaciality of their PERC cells for reference, which are listed in the table below. JinkoSolar tops the list with a record efficiency of 24.38% it attained in March 2019 and the typical production efficiency is at 22.96. Several companies announced typical efficiencies above 23% and the range in bifaciality between 65% and 75%. Bifacial PERC is not just limited to monocrystalline, but also applicable to multicrystalline cells – and Canadian Solar is a frontrunner in this area. The multicrystalline PERC cells of the company show average efficiencies of 20.8% with a bifaciality of 72%.

3.2 n-PERT & Passivated Contacts

While PERC has been the biggest breakthrough in the bifacial stream, it also has its limitations as a technology as well as with regard to bifacial solar. PERC is climbing the efficiency ladder so quickly that it is expected to reach the practical limit very soon, and the bifacial boost coming from PERC has been a bonus. PERC's bifaciality was good enough during the development phase of this cell technology, but its bifacial abilities are still limited compared to its peers. Now the industry is getting a flavor of the bifacial opportunities, especially in specific applications such as desert installations. And conditioning the ground to increase the albedo is not very complicated. Since bifacial technology is bankable, factors such as higher bifacialities are gaining prominence.

The industry has already been evaluating cell architectures based on n-type wafers, and n-PERT has been on the radar of a few industry participants. Although the technology exhibits next to best bifaciality of 80% to 90%, it has lost the efficiency battle with PERC. The average cell efficiencies with p-type PERC are now higher than for n-PERT cells, at least in a handful of cases. And the higher price of n-type wafers, which is about 3% to 5% more expensive than for p-type, also does not work in n-PERT's favor.

Efficiency Levels & Bifacialities of Selected Suppliers' Cells

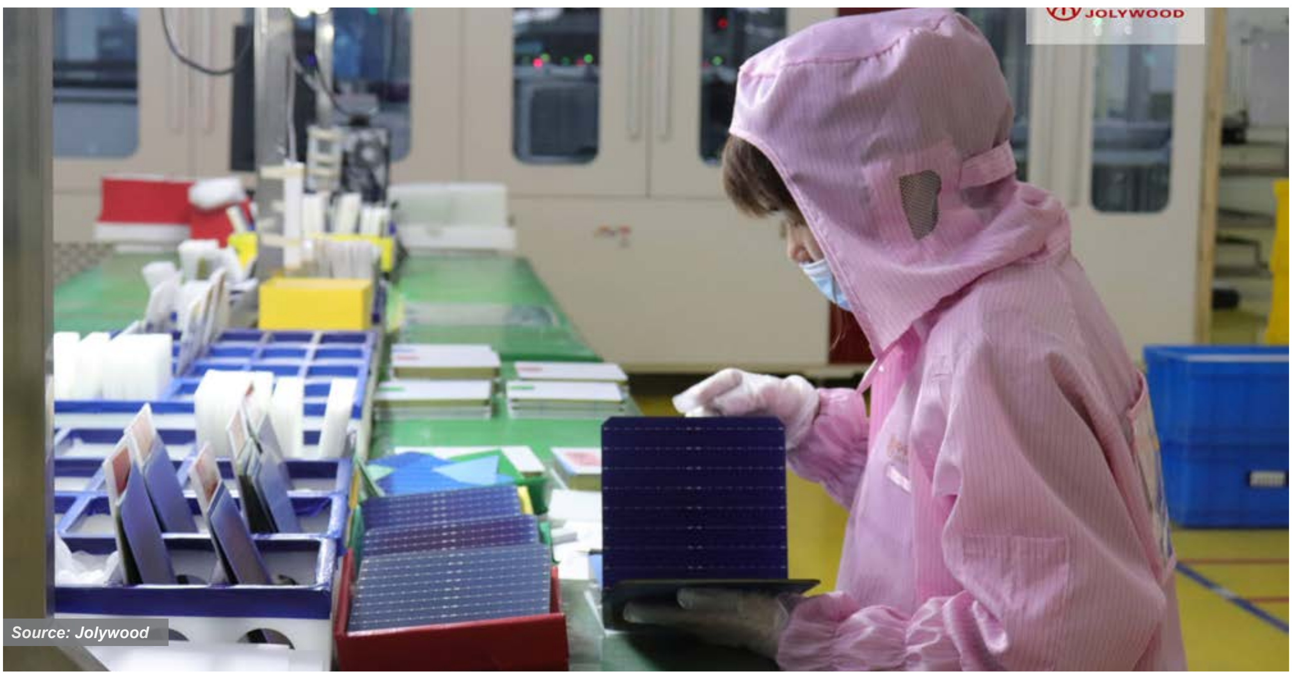


From PERC to TOPCon? When cell producers are looking at advanced cell architectures to succeed PERC as it approaches its practical efficiency limits, one hot candidate is TOPCon, which also promises to boost bifaciality up to 80% compared to PERC's level of 65 to 75%.

TOPCon technology is the next evolution step for n-PERT followers.It is also a possible upgrade to TOPCon for PERC makers with few changes to their existing processing lines. However, TOPCon also comes with its own limitations, especially related to bifacial solar. One of the inherent limitations of passivated contact cells is its low bifaciality due to absorption of light in the doped polysilicon film. At the current stage, the bifaciality of about 80% is lower than typical n-PERT when using silver, but better than PERC (around 75%). Using aluminum paste instead of silver on the rear side – an option that is under evaluation – may reduce bifaciality even further. And as with other n-type cell structures, passivated contact cells typically implemented on n-type substrates also use silver on both sides, which cannibalizes part of its performance benefits. For further details about TOPCon technology, check TaiyangNews' report on High Efficiency Cell Technologies 2019, or check the TOPCon Day recordings of our December held High Efficiency Solar Cell Conference 2020.

There are still only a small number of companies that are commercially producing passivated contact cells. Jolywood currently owns the highest TOPCon production capacity of 2 GW at cell level, converted entirely from n-PERT cell architecture. The company is planning to reach 3 GW by end of 2021. The Chinese company said it is producing cells with average efficiencies of 24%; its champion cell has an efficiency of 24.5% and bifaciality of 80%. Trina Solar installed a 500 MW line in 2019. While the company has not indicated its production efficiency, it held the record efficiency for TOPCon cells at 24.58% until June 2020, when it was surpassed by JinkoSolar, reaching 24.79%. Only about half a year later, JinkoSolar broke its own record in early January 2021 by achieving 24.9%.

While commercial activities are yet to become apparent, passivated contacts technology gained traction among multicrystalline manufacturers, at least in terms of setting efficiency records. Trina Solar attained 23.22% efficiency on an n-type cast-mono silicon substrate by implementing its i-TOPCon technology in November 2019. And Canadian Solar reported 23.81% efficiency on n-type multicrystalline wafer using PASCon technology, the company's brand for passivated contacts.However, with the days of multicrystalline technology seemingly numbered, this path very likely won't help spreading TOPCon technology.



Source: Jolywood

TOPCon tradeoff: Due to unwanted light absorption in the polysilicon layer on the rear side, TOPCon has a lower bifaciality than PERT, the fundamental technology on which it is built on. Still, the leading TOPCon cell supplier Jolywood offers products with efficiencies of around 24% and 80% bifaciality.

Bifacial TOPCon Cells

Characteristics: Typically employed with n-type base wafers; upgrade to n-PERT by adding a stack of tunneling oxide and polysilicon on rear side.

	Topics	Status	Comments
Process	Influence on process sequence	✓✓	In addition to applying interfacial oxide and polysilicon, TOPCon also requires additional diffusion and related cleaning steps
	Additional process tools required	✓✓	Requires tool(s) for tunneling oxide and doped polysilicon; boron diffusion furnace or ion implantation tools are new for emitter formation.
	Influence on passivation configuration	✓✓	Aluminum oxide is applied on front and rear of the cell structure; combines the functions of a passivation layer and a contact
	Influence on metallization	✓	Requires silver pastes on both sides; front side silver paste doped with aluminum is mainly used; low temperature fired pastes are preferred for rear side metallization
Production	Status of commercialization	✓	A handful companies are producing TOPCon cells in commercial quantities
	Availability of production equipment	✓	While LPCVD is available commercially, it suffers from wraparound; other technologies are not yet available commercially
	Additional costs	✓	Several solution providers are showing costs are similar to PERC; metallization costs are high due to using silver contacts on both sides
	Challenges	✓✓	Deposition methods without wraparound are not fully commercial and lower bifaciality than peer cell structures based on n-type
Performance	Highest cell efficiency	24.90%	JinkoSolar holds record for TOPCon cell efficiency
	Highest cell efficiency in production	24.0%	Jolywood recently announced average production efficiency of 24%
	Bifaciality	80%	Bifacial by default; suffers from slightly lower bifaciality due to the absorption in polysilicon on rear, while efforts in progress to reduce the polysilicon layer thickness to overcome the limitations
	Top commercial bifacial solar module power	615 W	Module makers are often combining TOPCon modules with other module technofixes such as half cell, MBB. Jolywood offering most powerful TOPCon module with 615 W power using 78 cells of M10 size to date

Note: All comparisons are referred to PERC as base line.

Source: © TaiyangNews 2021

Truly bifacial: While there is no extra work required to turn a TOPCon cell into a bifacial product, the process to make passivated contacts itself involves a few additional steps compared to PERC.

3.3 Heterojunction (HJT)

Heterojunction is not just another high efficiency cell structure, but also boasts the best bifaciality. In fact, Panasonic's (formerly Sanyo) HIT modules were the first commercial bifacial products that were already available in the year 2000. HJT technology typically exhibits the highest bifaciality of all advanced crystalline cell technologies, reaching above 90%. That's because of its symmetrical structure and superior passivation attribute of the structure also on the rear side. However, as with other n-type cell architectures, HJT also requires a silver-based metallization pattern on both sides to be bifacial, which means higher silver consumption and adding to cost. Another drawback of HJT is that it uses low-temperature cured pastes, which means their paste consumption is high in order to achieve good conductivity levels. But there are alternative ways: interesting metallization options such as plating or employing innovative interconnection approaches such as MBB can significantly reduce paste consumption. For details on HJT, check our December released Heterojunction Solar Technology in 2020 report.

HJT has attracted a lot of attention over the last year. Currently, it is impossible to track the announcements. Several companies from different backgrounds – existing HJT players, new to PV and mainstream PV manufacturers – have announced expansion plans or their entry into HJT. Norwegian REC is perhaps the key initiator for the industrialization of HJT technology. The company, with the support of its then equipment and technology supplier Meyer Burger, set up a manufacturing line in Singapore with a capacity of 600 MW. REC is now in the planning stage for a new fab with a capacity of 4 GW in France.

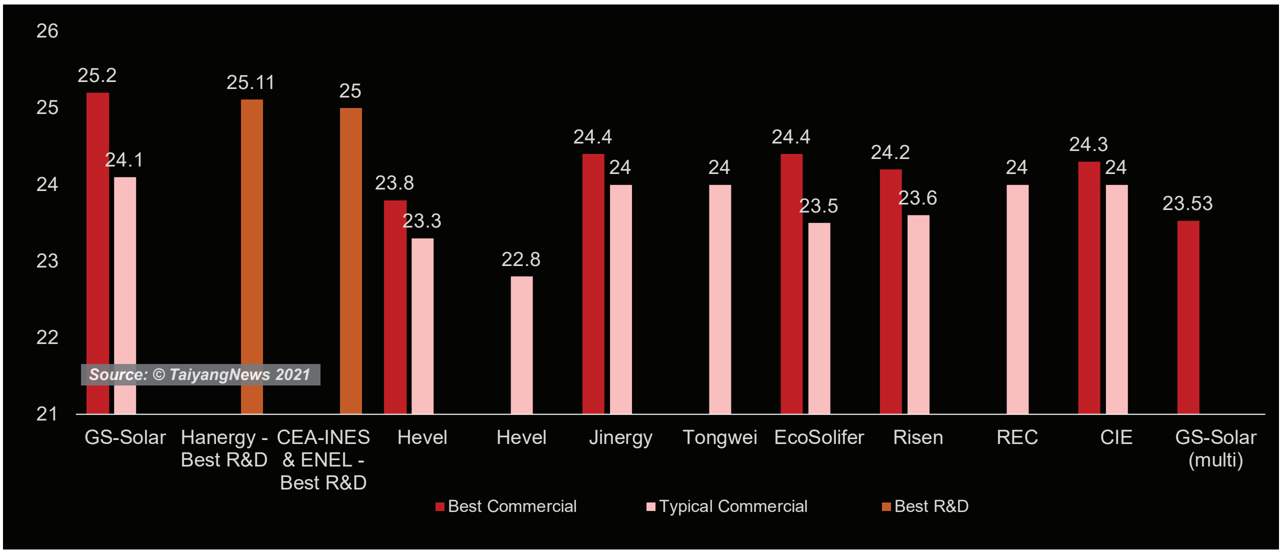
Risen Energy started a 2.5 GW HJT cell and module project in China at the end of August 2019, with plans to start production in 2021. Currently, Risen has a module capacity of 1 GW, while the 500 MW cell lines are in the ramp-up process.

The first cell line is in production with the highest production efficiency achieved of above 24.5%. Tongwei, in addition to the existing 400 MW HJT installed lines, has recently finalized the equipment suppliers for its next 1 GW HJT fab in China. HJT is part of its gigantic plans to build 100 GW production capacity by 2023.

Hevel has a cell and module production facility with a capacity of 340 MW in Russia.

HJT gaining traction: HJT technology that comes with leading bifaciality levels is attracting a lot of interest; Risen for example is in the process of building a gigawatt-scale fab with an estimated capacity of 2.5 GW.

Cell Efficiency Levels of Different HJT Producers



Route to high efficiency: HJT not only offers the highest bifacial yield, it is considered by many as a promising option to succeed PERC and mass produce cells with high efficiencies and superior LCOE. Some of the early HJT manufacturers claim they are reaching 24% in production.

The company is also the technology partner in a 1 GW HJT manufacturing project in its home country. There are several other companies including CIE Power, EcoSolifer, Enel, GS-Solar, Jinergy that have scaled up the technology into commercial production, with many eyes now looking at Meyer Burger. The Swiss company has decided to go captive and turn from a prime HJT production equipment supplier into a cell/module manufacturer with plans to start a 400 MW cell/module line in the second half of the year. The table above summarizes the efficiency levels of different HJT players.

3.4 IBC

IBC is the unchallenged efficiency leader among commercial silicon cell technologies. SunPower's cells used for its modules reach up to 22.7%. With a little tweaking back contact cells can produce power on two sides as well. However, SunPower spin-off Maxeon, the largest commercial producer of back-contact modules, is only offering mono-facial products so far. On the other hand, research institute ISC Konstanz has developed a low-cost IBC process called ZEBRA, which comes with a bifacial design. China's State Power Investment Corporation (SPIC) has licensed the process and has constructed a factory with a capacity of 200 MW. On this industrial line, SPIC was able to attain 23.6% average efficiency, while a champion cell reached 24% with a bifaciality of 70%. Italy's FuturaSun is also relying on Zebra IBC cells technology for its back-contact modules with efficiencies of about 21.28%.

In addition to these commercially available technologies researchers are working on different cell architectures. One interesting example is applying a passivated contacts structure on to the rear side of p-type PERC in a back junction configuration. The concept, developed by Institute for Solar Energy Research Hamelin (ISFH) keeps the strengths of the current PERC structure, that is, the formation of local p+ regions by aluminum screen printing and to replace the efficiency bottleneck, which is the phosphorus-diffused pn junction with its contacts, with a passivating contact, as described in a technical paper (A 22.3% Efficient p-Type Back Junction Solar Cell with an Al-Printed Front-Side Grid and a Passivating n+-Type Polysilicon on Oxide Contact at the Rear Side; Authors: Byungsul Min, et al.). In simple terms a PERC cell is flipped upside and down. The important feature of the approach is to employ aluminum fingers on the emitter side and Toyo is supplying such paste. "Finger widths of about 70 μm and height of 23 to 28 μm were attained using our pastes," said Dhamrin. A highest Voc of about 700 mV and 22.3% efficiency is realized with the concept, the paper noted.

Bifacial Heterojunction

Characteristics: A crsytalline silicon wafer is sandwiched between doped and intrinsic amorphous silicon layers

	Topics	Status	Comments
Process	Influence on process sequence	✓✓✓	Though the process sequence is simple it deviates completely from the standard
Process	Additional process tools required	✓✓✓	Requires a completely different set of process tools
Process	Influence on passivation configuration	✓✓✓	A totally different passivation scheme is applied; HJT is in principle a passivated contacts approach
Process	Influence on metallization	✓✓✓	Requires a special metallization process that can support low temperature process
Production	Status of commercialization	✓✓	More than a dozen companies are evaluating the process at least in pilot stage and few are offering commercial products
Production	Avalability of production equipment	✓✓	The production solutions are available from turnkey to individual processing tools
Production	Additional costs	✓✓	Several solution providers are showing that the LCOE is much lower compared to PERC; the conversion costs are high due to high capex and opex
Production	Challenges	✓	Supply chain is not robust yet; requires completely optimized metallization; high temperature sensitivity
Performance	Highest cell efficiency	24.90%	Hanergy attained 25.11% efficiency end of 2019
Performance	Average cell efficiency in production	24.0%	Several manufacturers incl. REC, GS-Solar, Jinergy and several other claim to have attained 24% efficiency in production
Performance	Bifaciality today / potential	80%	Several companies have attained bifaciality above 90%
Performance	Top commercial bifacial solar module power	615 W	Jinergy, among the first to upgrade to larger wafer size with HJT, in this case to M6, is currently offering the most powerful HJT module

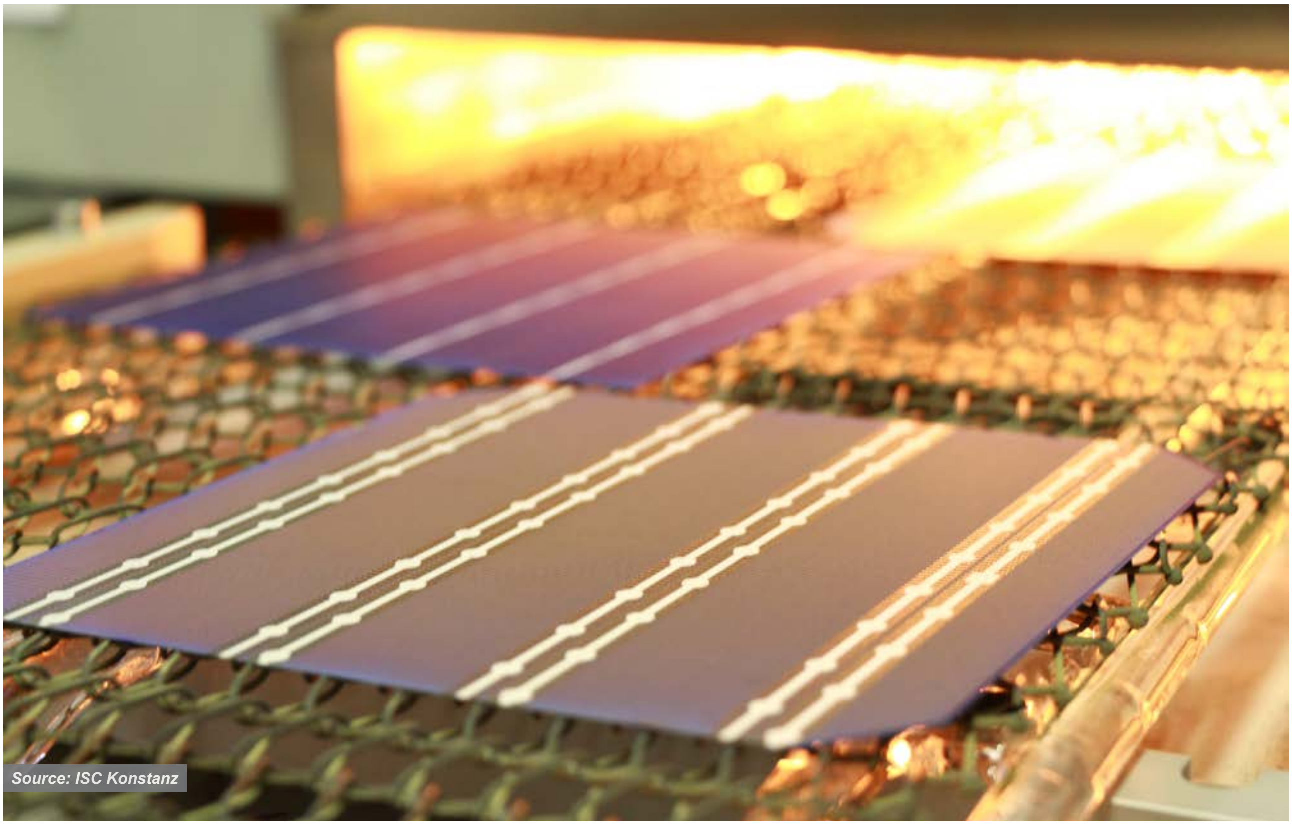
Note: All comparisions are referred to PERC as base line.

Source: © TaiyangNews 2021

Legend: ✓ Low negative impact; ✓ Medium negative impact; ✓✓✓ High negative impact; ✓ Low positive impact; ✓✓ Medium Positive impact; ✓✓✓ High positive impact; ✘ No impact;

Highest bifaciality: Like other n-type technologies, HJT is naturally bifacial, but its bifaciality of about 90% scores higher than its peers, in fact it is the highest among all cell technologies.

In summary, PERC is the most cost-effective solar cell technology as of today. Though not naturally bifacial, it can be easily converted without additional costs. Most of today's bifacial modules use PERC, which has helped to kick-start commercialization of bifacial technology to a notable scale. Since bifacial is bankable and PERC is reaching its limits, the move to more advanced cell technologies will also result in greater benefits from higher bifaciality. This larger selection provides the opportunity for developers and EPCs to choose a cell technology based on installation sites. If the site albedo is low, cell technologies such as PERC or IBC are sufficient. But regions with lots of snow or installations on white-painted roofs can benefit a lot from high bifaciality technologies such as HJT.



Source: ISC Konstanz

Highest efficiency at lower cost? IBC has been stigmatized as a high efficiency but very high-cost technology. ISC Konstanz has developed a lower cost back contact cell version called Zebra that is also bifacial. Zebra has attracted the first customers, such as SPIC from China.

2021第十七届中国太阳级硅及光伏发电研讨会

17th China SoG Silicon and PV Power Conference

November 2021, Yangzhou, China

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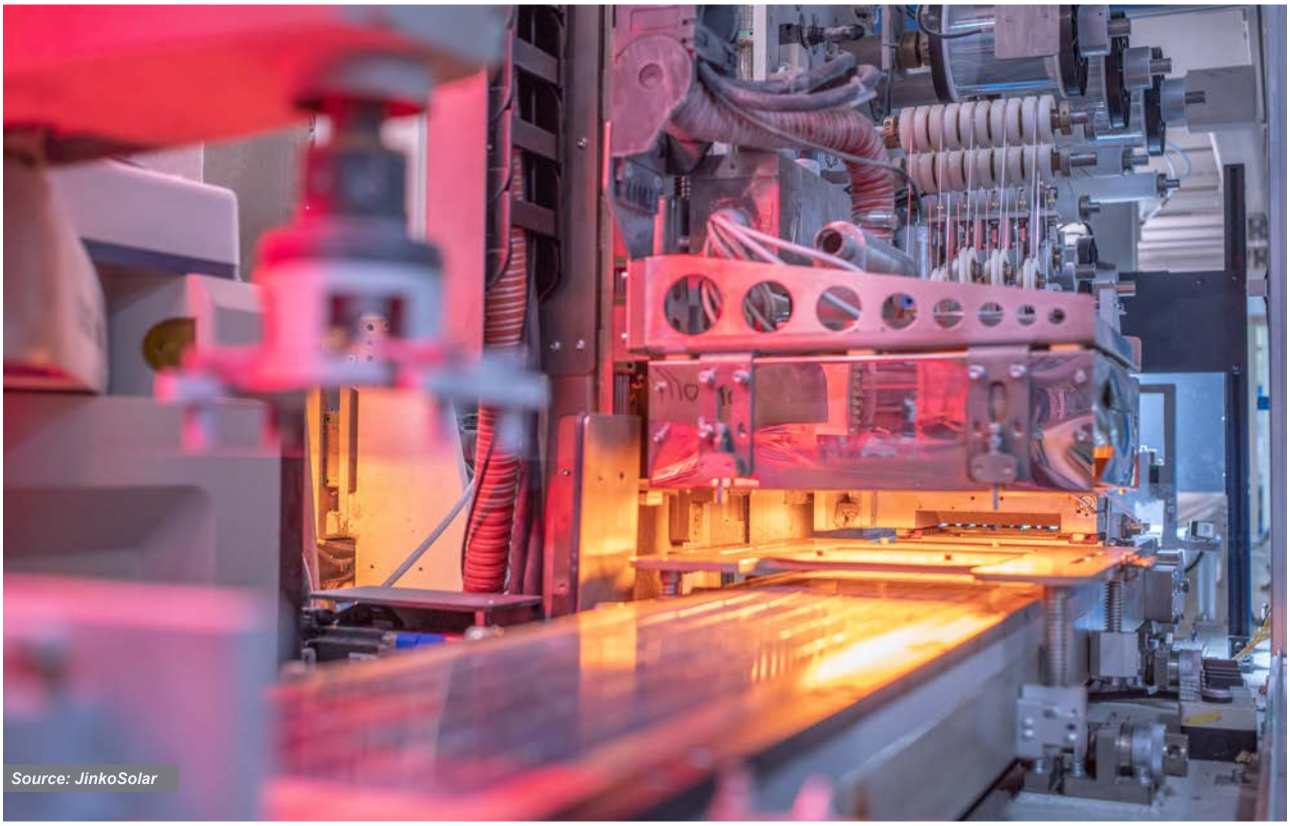
4. Bifacial Modules

Like for cells, bifacial technology requires a couple of alterations at the module level as well. An inevitable change is switching to a transparent rear cover, which is obviously required in order to facilitate the absorption of sunlight from the rear side. In addition, changing the junction box design, opting for alternative encapsulation material and implementing more suitable interconnection approaches help in maximizing the benefits from bifacial architecture.

4.1 Interconnection

As for interconnection, the first process step in module making, the bifacial technology as such does not need any specific changes. However, the beauty of the technology is that it can be combined with almost all advanced module technologies that essentially optimize the interconnection process. It is a perfect match to half-cut module design, as the gain from bifaciality is mainly reflected in higher currents, which also results in greater losses. Thus, a half-cell configuration is better for interconnecting bifacial cells, as it reduces resistance losses. No wonder half-cell module technology is quickly gaining acceptance among module producers.

Multi-busbars are yet another advanced interconnection approach that augments the benefits of bifacial technology. An increased number of busbars enables reducing the finger width, which is especially very valuable for bifacial PERC that uses relatively thick aluminum fingers. Thin fingers reduce shading and, thus, improve power generation. Module producers such as JinkoSolar are offering bifacial panels in combination with advanced zero space module technologies, which the company calls Tiling Ribbon.



Source: JinkoSolar

Pretty much the same: As for interconnection of solar cells, a key step in modules manufacturing, bifacial technology requires no specific changes.

4.2 Module BOM

A key for bifacial module manufacturing is to replace the opaque backsheet. The choice is between glass and transparent backsheet, and each approach has its own merits and limitations. Going frameless has been a long-sought goal for the PV industry.

Glass: The bifacial boom actually started with a glass-glass configuration. And glass as rear cover indeed has several advantages. Independent from any bifacial requirements, PV manufacturers have seriously evaluated glass-glass configurations, which has given them the confidence to extend the performance warranty for their modules. While standard backsheet modules have a typical degradation rate of about 0.7% per year, the degradation of glass-glass modules is reduced to 0.45%, based on which nearly every glass-glass module product is offered with a 85% power output warranty at the end of 30 years. This is 20% higher than the typical 25 years offered for glass-backsheet panels.

The increased interest in glass-glass configuration was also fueled by a considerable reduction in glass prices at the end of 2018 and 2019, even for thinner glass, whose prices were comparable to that of a good quality backsheet. Though glass prices went up again in recent times due to a supply shortage (and thus offering an opportunity for transparent backsheets), glass has remained the primary choice of rear cover in bifacial modules. While 3.2 mm glass is typically used as the front cover in glass-backsheet configurations, there is no such 'standard' thickness for the rear cover used in bifacial modules. Glass being the main contributor to module weight, using the same 3.2 mm glass also on the rear side simply doubles the weight of the solar panel. Thus, relatively thinner glass of the same thickness on both sides is typically used in bifacial modules. Even using thinner glass, a glass-glass configuration is usually still somewhat heavier, which is especially disadvantageous during the time of system installation.

Source: JinkoSolar

Best fit: Since the bifacial gain is mainly reflected in the current, the half-cell design with a promise to reduce current related losses is a great fit for bifacial technology.

On the other hand, module reliability, especially the mechanical loading, is affected by reducing the thickness of the glass. The influence is more pronounced with larger modules.

Thus, an optimum value has to be determined by carefully evaluating the tradeoff between module size, glass thickness and reliability. Last year, bifacial modules were available in the market with different glass thicknesses, mainly 2 mm and 2.5 mm, but there is clear march towards the thinner variant. Except for a few handful of companies, the commercial bifacial modules from leading suppliers are using 2 mm glass as rear cover. Independent of module size, 2 mm glass seems to have proved to be reliable. One example, the most powerful bifacial module with a power rating of 655 W built with 66 of G12 size cells offered by Canadian Solar Inc. (CSI), has a size of above 3 m^2 but uses 2 mm glass on both sides.

Regarding weight, the most optimal solution in a glass-glass configuration would be to use 1.6 mm glass on both sides, which equates to the weight of a standard module using 3.2 mm front glass. LONGi Solar has already started working in this direction. However, such a thin glass does raise reliability concerns. According to LONGi Solar's vice president Lv Jun, reliability depends on the module size; and larger modules with thin glass may not qualify for mechanical load related reliability obligation. However, modules with M2 cell sizes in 60-cell configuration can meet the requirements with 1.6 mm glass. "A 72-cell module size with M2 cell size is a no go for 1.6 mm glass," underscores Jun. But there might be solutions. Jun suggests a possible workaround of using frames with higher mechanical strength that can compensate for the weak mechanical properties of the thin glass.

Framed vs Frameless: There has also been the classical question of whether the bifacial (or glass-glass) module should have frames. The cost coefficient added to the question makes it even more interesting, because frames contribute a considerable amount in this regard – about 10% of total module costs and about 20% of module BOM costs. In principle, bifacial modules can be frameless. During the early days of bifacial technology development, several module producers were counting on the possibility of eliminating the frames altogether, mainly to cut on cost. Avoiding frames also eliminates the problem of dust accumulation and any shading from the frame. On the other hand, frameless modules come with the risk of breakage during transport and installations. There are also concerns about mechanical stability of frameless modules. The risk increases with modules becoming larger. There is also some resistance from installers and EPC companies towards frameless modules, as installers would have to invest in larger clamp sizes to match the mechanical stability of standard modules, which makes this option costlier.

Today's bifacial modules are available in three configurations – framed, frameless and edge protected. However, when it comes to sales, framed modules, which are simply a drop-in replacement for standard panels, are the mainstream. A framed bifacial module has better performance on mechanical properties and anti-aging characteristics under tough environments compared to a monofacial product. Frames also support cleaning of modules with automatic cleaning machines in the field. While frameless products have indeed a direct cost advantage when looking at the module, they require dedicated design of a support rack. That's why framed glass-glass modules are the preferred solution today.

Transparent backsheet: Using a transparent backsheet as rear cover of the bifacial module is an interesting alternative to glass. The approach also comes with several advantages. Bifacial modules based on transparent rear cover naturally weigh the same as a standard module with an opaque backsheet. Thus, the handling and logistics remain unchanged without any need for extra care. Moreover, the production process and the structure for bifacial technology are no different to traditional modules. Unlike glass-glass, manufacturers can use standard lamination machinery and processes without lowering throughput.

In addition, polymer backsheet modules are "breathable," meaning they allow moisture and free radicals formed with EVA to escape. As a result, the bifacial modules with transparent backsheets can continue to use EVA as an encapsulant. And by reducing one layer of glass from the module structure, the backsheet variants reduce the degree of risk with potential-induced degradation (PID).

The polymer rear cover is also less prone to soiling, thus reducing the effort of cleaning as part of operation and maintenance. In hot regions, it also makes sense to use backsheet panels, because heat dissipation is better than with glass, thus helping to lower the cell operating temperature by 5 °C to 10 °C, making them more efficient.

On the downside, transparency of such a backsheet is slightly lower than glass at 89% to 91%, and decay is also higher at 10% to 15% over the module's lifetime. However, backsheet suppliers argue that the absorption on the rear side is not critical and there has been a continuous effort to improve it. As for the decay in transparency, they point to the fact that the transparency of encapsulants also goes down over time; in other words, using glass would not bring any additional benefit here.

However, glass became the back cover of choice at the time bifacial modules started entering the market in a big way in 2018. At the time, opting for glass was mainly due to the fact that there was no competent polymer solution available for meeting the needs of bifacial module technology.

One of the unique selling propositions for glass-glass modules has been the 30-year performance warranty. A common belief is that glass-glass technology performs well in reliability tests, such as mechanical loading and damp heat tests.

A component supplier to backsheet producers, DuPont, says that the extended warranty offered with glass-glass is based on fragile testing conditions such as 3,000 hours of damp heat test, which hardly mirror real-world conditions. DuPont also points to the fact that there is no field data to support the claim of longer durability of glass-glass modules. On the other hand, modules using first generation transparent backsheets have a proven track record of more than 15 to 20 years, according to DuPont. However, nearly every backsheet maker argues moisture ingression into any kind of module is from the sides rather than the rear, which is also true for dual glass modules.

Source: DuPont

Transparent backsheets: DuPont, with a transparent variant of its Tedlar product, is at the forefront of promoters for bifacial modules with transparent backsheets. It argues that modules using backsheets made with its Clear Tedlar can also be offered at 30-year performance warranty, which JinkoSolar already does.

But unlike standard PV panels in which the moisture has a chance to escape from the rear, the glass-glass module blocks that route. Thus, degradation could be worse for glass-glass modules when proper care is not taken.

In any case, backsheet manufacturers have been making commendable progress with their transparent products. According to Cybrid's CTO Li, during the early days of transparent backsheets, developers were mainly focused on making the backsheet less expensive than glass, but there has been a shift in this focus over the last two years towards making a reliable backsheet. He underscores that the current generation of backsheets have certainly improved on reliability and are robust enough to be used in bifacial modules. A unique advantage of glass-glass modules has been that they come with a 30-year warranty. With the first bifacial glass-transparent backsheet based modules now matching the 30-year warranty, glass-glass modules cannot lay exclusive claim to it anymore. DuPont has been a strong advocate of extending the warranty on backsheet-based modules. The supplier of proprietary PVF (Tedlar) films to backsheet laminators introduced Clear Tedlar, a transparent variant of its product, in 2018. It has been promoting the idea that transparent backsheets using its Clear Tedlar can provide the same, if not better, reliability than glass.

JinkoSolar, the largest module maker, was convinced with the idea and is now leading the league. The Swan module series of the company was the first module series offered in both variants – glass and transparent backsheet as rear cover. Jinko is so convinced with the technology that it is currently offering the third generation of modules with transparent backsheets. Its previous Tiger and the current flagship module of the company Tiger Pro series bifacial variants are offered with transparent backsheet. All the products based on transparent backsheets exclusively use Clear Tedlar as the rear protective layer.

Source: DuPont

Growing interest: An increasing number of module producers is showing interest in using transparent backsheet instead of glass as rear cover in bifacial modules. The polymer-based solution eases the shift to non-standard module sizes originating from a large variety of wafers sizes floating in the market. Moreover, a glass shortage has been supporting the business case for suppliers of transparent backsheets.

Long life with backsheets: Jolywood is not only a leading supplier of transparent backsheets, but the TOPCon bifacial modules of the Chinese company featuring its transparent backsheet also come with a power warranty of 30 year, which was exclusive for glass for the many years.

In a presentation at TaiyangNews' Webinar on bifacial technology in December 2019, Jinko emphasized that the PVF film results in an anti-staining effect due to its hydrophobic nature, in turn reducing the need to clean the module's rear side, which is one of the more difficult tasks in operation and maintenance of solar farms.

Jolywood is also offering Tedlar-based bifacial modules with a 30-year performance warranty. Companies such as LG, Jinergy and Talesun are marketing bifacial modules with transparent backsheets, but the performance warranty is limited to 25 years. The number of companies showing interest in transparent backsheets is steadily increasing, according to DuPont 's global marketing manager Mark Ma. This is because one of the major trends in module making is to use larger wafers. With larger wafers, the size of the module also increases, correspondingly increasing the weight. And this is where using transparent backsheets proves beneficial – by not burdening the module with additional weight. Glass-glass modules are now offered with different glass thicknesses, which are not mainstream. The module size also varies considerably as there is no standard for wafer size in the current market. Thus, procuring thin glass suitable for different module sizes could be challenging. Ma emphasizes that module makers are employing new materials in glass-glass configuration such as thin frames and different encapsulation materials, which do not have sufficient field reliability data. Using transparent backsheets can help keep BOM close to the standard, he said.

Lucky Film and Jolywood have been the first companies to offer transparent backsheet products based on Tedlar, which they have also supplied in larger volumes. Leading laminators working with DuPont are ready with a Tedlar based transparent backsheet product, according to DuPont.

Jolywood is somewhat different in the context of transparent backsheets. The company, in addition to being one of the market leading suppliers of backsheets, also owns high efficiency cell and module manufacturing facilities of respectable size. Apart from JinkoSolar, Jolywood is the only PV producer that is offering a 30-year power warranty for its transparent backsheet based module products so far. The company is also one of the suppliers of Tedlar based backsheets to JinkoSolar. Another specialty of Jolywood, according to Yuan, is that the company is providing an extended 30-year warranty also for non-Tedlar backsheet based modules, for example, for modules using backsheets with double sided coatings.

All component suppliers and most backsheet manufacturers are offering solutions suitable for transparent rear covers. DuPont introduced the transparent variant of its Tedlar in 2018, and Fumotech is currently supplying the third generation of its transparent PVDF film. Transparent backsheets are becoming available in almost all structures as those of the standard opaque products. DTF has also added a range of ultra clear products to its Mylar UVHPET portfolio for bifacial applications. The films are designed to be used as outer, inner or mono layers in transparent back sheets.

Cybrid, the market leader of the segment, is promoting a transparent variant of its top configuration – KPf. Jolywood is mainly promoting transparent backsheets based on double-sided coating. And being an important laminator for DuPont, TPC is also at the top of its list. Globally leading EVA supplier Hangzhou First, which also offers backsheet products, is mainly promoting CPC and KPC configurations, while the TPC structure is also part of its product portfolio.

Today's bifacial modules can be built with different outer packaging configurations – glass-glass, using thinner glass, framed, frameless and with transparent backsheet. Every approach has its own technical advantages and limitations, also depending on applications; that's why JinkoSolar, for example, offers both bifacial modules with glass-glass and glass-transparent backsheets, as they explained during a presentation at the recent TaiyangNews Advanced Module Technology Conference. However, for the moment the preferred bifacial configuration remains glass-glass modules with frames.

Patterned rear cover: One inherent limitation of bifacial technology is that it cannibalizes the front power by about 4%. The loss in performance is due to the usage of the transparent rear cover, which allows the light hitting on the inter-cell spaces to simply pass through. In case of monofacial modules, these empty spaces are covered by opaque backsheets.


Source: Hangzhou first

Protecting front performance: Bifacial modules suffer from slight performance losses on the front side due to the absence of reflection gains from intercell spacing. Unless a grid backsheet, such as this one from Hangzhou First, helps restoring reflection benefits.

The light hitting these inter-cell spaces is reflected onto the glass, which again undergoes total internal reflection and is sent back onto the cell surface, offering it a second chance to get absorbed. Bifacial modules obviously miss this effect.

A couple of years ago, glass suppliers came up with an innovative solution where the rear glass is printed with white reflectors that fill in the empty spaces, while the areas that would be occupied by the cells remain transparent. This mimics the role of a white backsheet in a standard module, which makes the bifacial solar panel look like a monofacial module from both sides.

The trick of the glass companies can be replicated on backsheets as well. Backsheet makers have also started offering such tailored products, colloquially referred to as grid and/or patterned backsheets. The approach helps in earning back the front power in a bifacial structure; actually it's even a bit more in real operating conditions. The reflectors are more effective when the light is hitting at greater angles, which is not the case with STC.

Source: Hangzhou first

Black for beauty: After alleviating power losses of bifacial modules through grid backsheets, its suppliers, such as Hangzhou First, are exploring other options. One product is a black colored grid to be compatible with all black modules that boast aesthetics.

According to Jolywood, this "results in about 1.2% power gain" compared to bifacial panels using a plain transparent rear cover. All major transparent backsheet suppliers – including Jolywood, Cybrid, Hangzhou First – are offering patterned transparent backsheets. And some companies, such as Jolywood and Hangzhou First, are even offering grids in black color for better aesthetics.

Encapsulation: While not relevant to transparent backsheets, glass-glass bifacial modules also require one more change in the BOM. The widely used EVA for encapsulation in standard modules is not optimal for the glass-glass structure. It comes with one major shortcoming as the acid formed during the lamination cannot escape from the glass-glass structure. For this reason, the majority of glass-glass module manufacturers have replaced the EVA with polyolefin products. In addition to superior reliability attributes, polyolefin encapsulants also suppress PID. Bifacial modules are more PID prone due to the presence of glass on both sides of a module and the presence of aluminum in the rear passivation layer of PERC cells. The other benefit of POE is it features 10 times better moisture barrier properties. Taking these benefits into account, most of the glass-glass modules are made with POE as the encapsulant.

Of late, a new trend seems to be emerging. Instead of using a single layer of POE, module manufacturers are showing interest in a coextruded film with multiple layers. This started when one of the top tier PV producers was looking for an alternative to POE, especially to reduce costs. The rationale behind it was that POE is relatively about 50% more expensive – and the prices are mainly driven by the core resin prices on a "/kg" basis. One possibility to reduce costs is by thinning down the POE and compensating for that material loss with EVA. However, there were some practical constraints. Although raw material cost of coextruded polyolefins is a little bit lower, the production process results in low yields as the produced film has to be cut on two sides to make a roll. The waste from the cutting cannot be recycled, as the waste is a mix of polyolefin and EVA. The coextrusion process is also slower, according to Cybrid. Therefore, the coextruded product has similar costs as that of a single layer POE film.


Source: Cybrid

POE preferred: The widely used EVA for encapsulation in standard modules can cause issues in glass-glass structure that can be avoided if POE encapsulants are used.

And yet, the multilayer structure comes with a set of advantages that make it more appealing. It is very easy to generate bubbles during the lamination process when using this pure polyolefin film, if proper care is not taken. And the lamination time is also longer, requiring roughly 6 minutes more per lamination cycle. The extruded film not only reduces the possibility of forming bubbles during the lamination, it also supports shorter cycle times. The lamination time in the last chamber is about 600 seconds with polyolefin and 300 seconds with EVA, while coextruded film finds the middle ground at 450 seconds.

Source: Cybrid

Next gen POE: A multi-layered POE-EVA-POE structure is under serious pursual to address some of the inherent short comings of simple POE films – and Cybrid is one among a handful companies that have the capability to supply such coextruded films.

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Next, the multilayered structure is more beneficial in making MBB modules using round interconnection media, which are slightly displaced during lamination when using pure POE film. The coextruded film keeps the round ribbons intact. Another advantage, according to Cybrid, is that the adhesion of glass to a multilayer structure is better than polyolefin.

While the reasons are not known, the coextruded encapsulant exhibits better anti-PID behavior compared to polyolefin-only films. Hangzhou First has installed 10 new production lines for coextruded films, while Cybrid says all of its production lines are already compatible with coextrusion. And the two companies, along with HIUV, are ready to supply multilayer encapsulants.

Junction box: Repositioning of the junction box to avoid shading on the rear side is one specific change that should be considered in designing a better bifacial module, in particular as it doesn't require much effort. However, the possible current mismatch using typically positioned junction boxes is not significant, as the photocurrent generated from the rear side is mainly based on low level diffused light. New junction box designs suitable to be placed in the corners are available from several vendors. The majority of the bifacial modules from leading vendors are now based on this optimized design.

5. Characterization of Bifacial Cells & Modules

One of the main challenges with bifacial PV was how to test and label the solar module. While this has not been solved completely, there is a substantial improvement. IEC released a standard called IEC TS 60904-1-2 in the beginning of 2019. However, the standard is prefixed with TS, an abbreviation for Technical Specifications. TS standards are close to International Standards in terms of detail and completeness, but are yet to be accepted as an International Standard either because of lack of consensus or because standardization is seen to be premature. So the jury is still out on a globally accepted and fully mature standard for measuring bifacial devices.

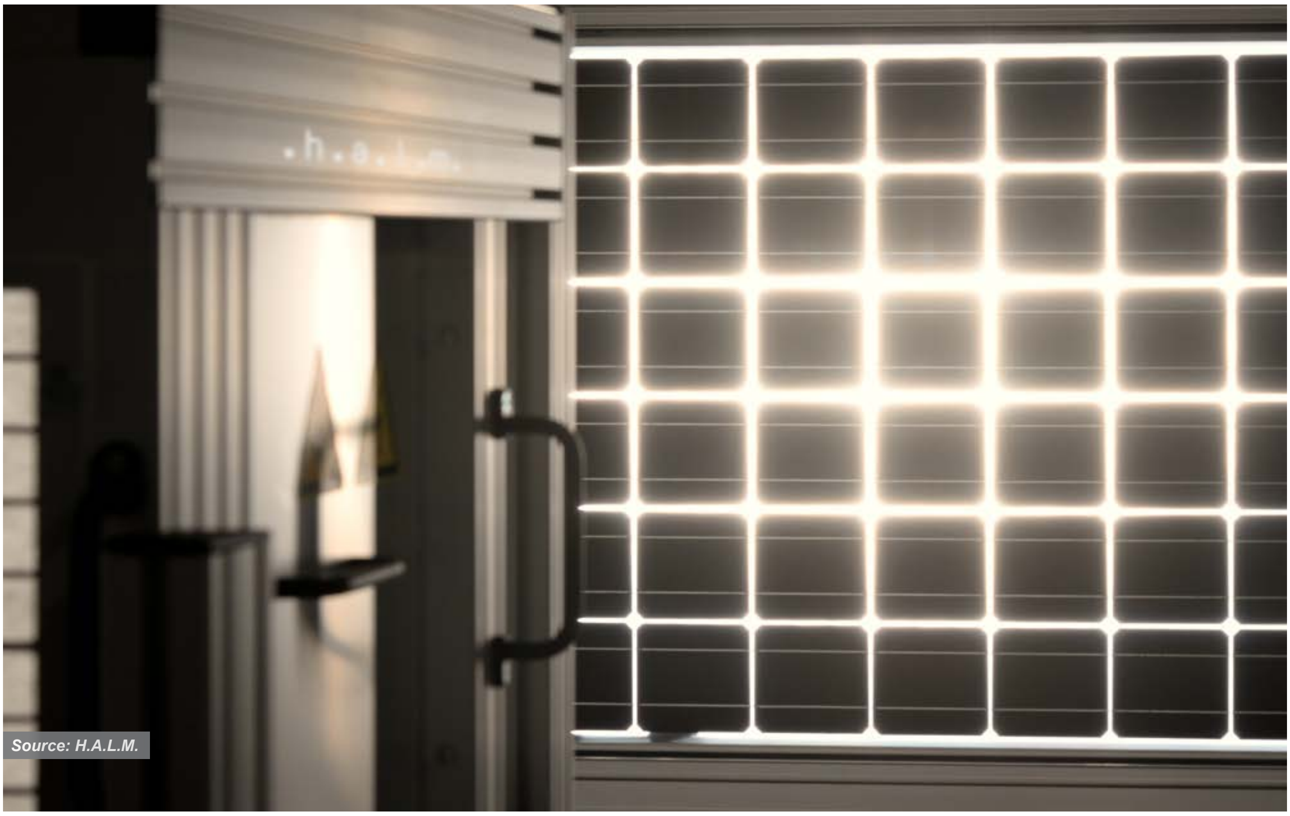
However, the proposed IEC TS 60904-1-2:2019 standard is an important step and describes the procedures for measuring I-V characteristics of bifacial photovoltaic devices in natural or simulated sunlight. The standard is applicable for all varieties of bifacial substrates – cells, sub-assemblies of cells and modules. It also covers the PV devices designed for use under concentrated irradiation if they are measured without the optics.

The standard approves the measurement of the bifacial device by illuminating from the front side alone as well as illuminating simultaneously from both sides. The procedure to illuminate from the front alone is as follows: the front and rear side of the module is illuminated from the front and rear at STC conditions to determine bifaciality, which is the ratio of front and rear electrical characteristics of the bifacial module. This must be accomplished with a non-irradiated background. The background is considered to be non-irradiated if the irradiance is measured to be below 3 W/m^2, on at least two points, on the non-exposed side of the device. Isc is considered as the key parameter. In the second step, the power generation gain yielded by bifaciality is to be determined with an equivalent irradiance level on the front side. For example, for a device with 80% bifaciality on Isc, the irradiance equivalent to 1 sun (equal to 1,000 W/m^2) on the front and 200 W/m^2 on the rear side would be 1,160 W/m^2. Similarly, for 100 W/m^2 rear side illumination, the equivalent irradiance would be 1,080 W/m^2. The sun simulator is then calibrated to irradiate just the front side with these equivalent irradiance levels. It is proposed to report two maximum power values per module with 100 W/m^2 and 200 W/m^2 for the rear side characterized as PmaxBiFi10 and PmaxBiFi20, respectively.

Alternately, double-sided illumination can also be used to determine the IV characteristics of a bifacial PV device. For this, a sun simulator with two light sources is required. Specs for such a sun simulator are no different to the standard, except that it has to meet all criteria with double-side illumination. As defined in IEC 60904-9, the non-uniformity of irradiance, the spectral distribution and the temporal instabilities of irradiance must be measured on both sides when the test area is simultaneously illuminated. The non-uniformity of irradiance must be below 5% on each side. Measurement here is quite straightforward. The front side is illuminated with 1,000 W/m^2, while the rear is flashed at two levels – 100 W/m^2 and 200 W/m^2. The following steps for reporting power are essentially the same as the method described above for single-side irradiance. In both cases, the module is labeled with the resulting power – $W_{Peffective}$.

H.A.L.M. believes in measuring with illumination on both sides. The German company says that it examined the front and rear side short-circuit current of industrially-produced bifacial substrates from different manufacturers and observed variations in the bifaciality coefficient of up to 10%. The testing equipment provider used this variation to deduce the additional measurement uncertainty of the single-side illumination approach caused by the assumption of constant bifaciality. With the rear side irradiation reaching 20% of the front side irradiation value, H.A.L.M. found that the additional uncertainty ranges between 0.7% and 2.0% relative to the different batches. Naturally, H.A.L.M. is offering IV characterization tools with double sided illumination. However, since H.A.L.M. has a strong foothold in the cell tester segment, its bifacial solutions are also mainly aimed at cell characterization.

Wavelabs, also from Germany, is another provider of IV testers with double sided illumination for testing cells. Unlike tools from H.A.L.M., Wavelabs' tools are equipped with a LED light source.



H.A.L.M., a leading supplier of sun simulators, advocates for testing bifacial devices from both sides with two light sources simultaneously, as shown in this photo.

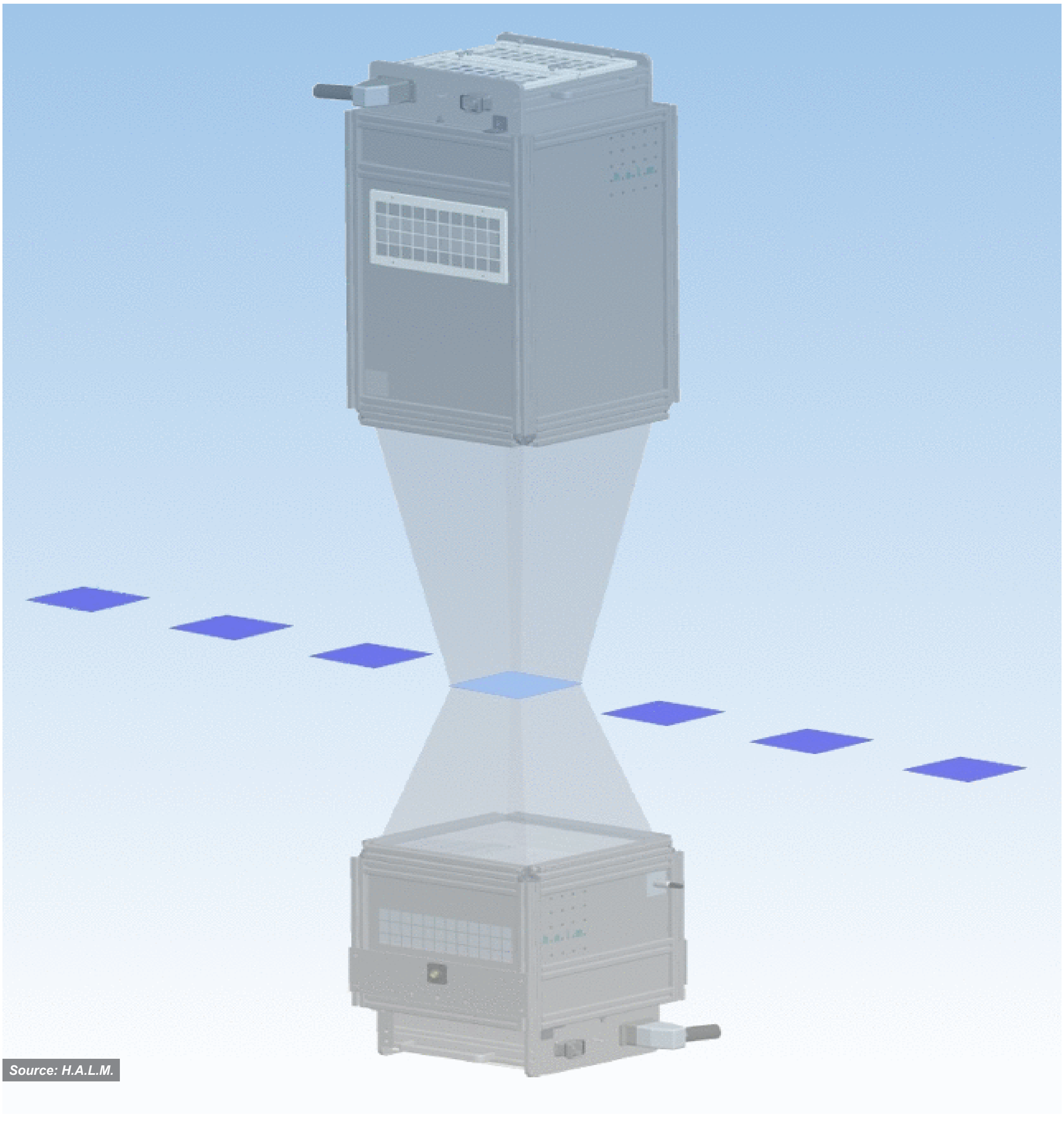
In addition to general advantages of LED, such as longer lifetime of light source, the tester from Wavelabs enables illuminating the cell with different wavelengths on the front and rear. According to Wavelabs' Jason Nutter, the LED device allows flashing the cell with blue light on the front and rear. This enables obtaining the spectral response of the surface, which allows the characterization of passivation and metallization.

Wavelabs' LED tester provides three separate measurements – front, rear, and a combined measurement where the user can specify rear side illumination intensity without restrictions.

For module level IV measurement of bifacial, Pasan, a division of Meyer Burger, was a strong advocate of the accomplishing measurements from one single-side measurement, underscoring double-side illumination is not optimal for high-volume mass production. However, the Swiss-based premium quality supplier is now also offering a bifacial characterization tool with double-side illumination.

On the other hand, since it took quite a while to establish the TS, there is no common approach among the leading module makers when it comes to measuring and labeling. One of the world's leading pure cell manufacturers, Aiko, for example, is measuring both the sides simultaneously for proper binning of cells in order to avoid mismatch issues. At module level, there is a mixed practice. A few are measuring both the sides at STC and labeling only the front power along with bifaciality. However, the major companies TaiyangNews talked to are doing sample testing for the rear side at STC to assess if the modules are performing according to internal estimations. Adding rear power values on the overall power label is not yet a practice.

Even with a common practice in existence, the technology is still lacking in terms of guaranteeing the bifacial gain coming from the rear side.That's because the bifacial gain changes according to ground albedo, which again changes based on the location.



Double check for cells: Like with modules, H.A.L.M. offers equipment for IV measurements from both sides also for bifacial cells using two light sources. Here the throughput rate is much higher.

This is usually beyond the scope of module makers unless they know where the panels will be deployed – and even then, there remains uncertainty. And that is why PV manufacturers are not typically selling the rear performance, but charging a premium on the front power. While most of the companies we spoke to declined to give the exact price premium over the front power, the approximate value is probably between 5% and 10% higher, depending on the cell technology and bifaciality.

6. Bifacial Module Products

No doubt, bifacial solar still has some challenges to master as it is expanding its market share. However, a lot has been reached, regarding reliability, standards and other topics; and there's no fundamental issue left to hinder the technology's foray into the mainstream. Nearly every latest product from the leading module manufacturers is also available in a bifacial variant. The undeniable advantage of bifacial technology is that it can be combined with most of the advanced module technologies.

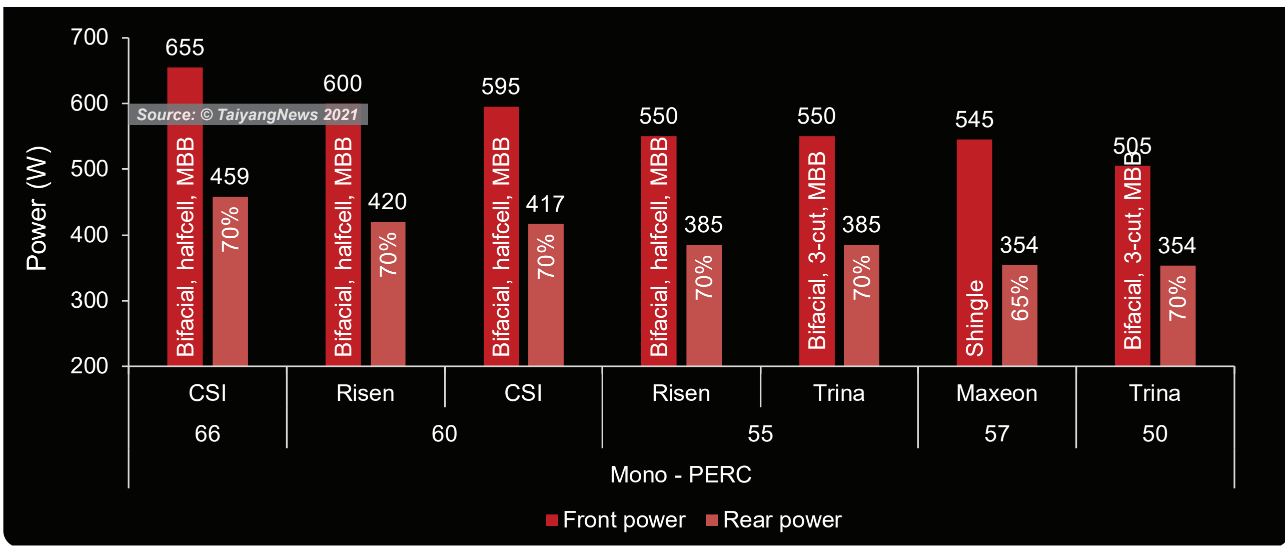
This is also reflected at the product level. We scoured through the data sheets of more than 300 products from 25 module producers for our late January released Advanced Module Technologies 2021 report. As part of this effort, we have also collected the data for bifacial modules – and 13 module makers confirmed specifications of 77 bifacial products collected. We analysed this information to see that the trend of increasing module power and sizes based on larger wafers is spreading rapidly.

Power Characteristics of Selected Bifacial Modules Based on G12 Wafer Size

Company	Product series	Wafer type	Cell tech-nology	No of cells	Technology	Effi-ciency (%)	Front power (W)	Rear power (W)	Bifa-ciality (%)
CSI	BiHiKu7	Monocrystalline	PERC	66 (eq.)	Bifacial, halfcell, MBB	21.1	655	459	70
Risen	TITAN	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	21.2	600	420	70±5
CSI	BiHiKu7	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	21	595	417	70
Risen	TITAN	Monocrystalline	PERC	55 (eq.)	Bifacial, halfcell, MBB	21	550	385	70±5
Trina	Vertex	Monocrystalline	PERC	55 (eq.)	Bifacial, 3-cut, MBB	21	550	385	70+/-5
Maxeon	Perfor-mance 5	Monocrystalline	PERC	57 (eq.)	Shingle	21.1	545	354	65
Trina	Vertex	Monocrystalline	PERC	50 (eq.)	Bifacial, 3-cut, MBB	21	505	354	70+/-5

Source: © TaiyangNews 2021

Power Characteristics of Selected Bifacial Modules Based on G12 Wafer Size



All about PERC: The bifacial modules based on G12 format from leading companies that responded to our inquiry are primarily employing PERC cells. Other higher efficiency advanced technologies are yet to be scaled to this largest commercially available wafer/cell size.

Another important and apparent trend is the use of multiple advanced technologies in one module product with bifacial being an important spice of this technology mix.

While it was our practice to segregate the module products based on technologies in the past, this has become obsolete. Because the most important attribute of the module, which is power, is now mainly a function of wafer size rather than the technology on which it is built on. Inline with the current developments, we have grouped the bifacial module products from leading companies according to the 4 mainstream wafer sizes – G12, M10, M6 and G1. There are a couple of products that have slightly different sizes, which we have clubbed with the nearest main size and indicated to keep the overview more simple. Below are the module product descriptions following the order of wafer size – from large to small.

G12 bifacial modules

The largest commercially available wafer size today is 210 mm full square, often referred as G12. So far, only four companies are mainly promoting such module products in the commercial space – CSI, Risen, Trina Solar and Maxeon, a spinoff from US-based SunPower. A total of 7 products are promoted by these companies and all are based on p-type PERC technology. These very large wafer sizes are brand new, introduced less than 2 years ago; thus other advanced cell architectures have not yet been implemented on these larger wafer formats. The major difference among these products is power, which is a direct function of the number of cells employed in building these modules. CSI is offering the most powerful bifacial module with a rated power of 655 W, which is built with the highest number of G12 cells, which is 66. The next lower cell count is 60, which is the base of module products offered by Risen and CSI that come at power ratings of 600 W and 595 W, respectively. Trina is offering 55 and 50 cell configurations with output power of 550 W and 505 W. Maxeon's shingled module comes with a labelled power of 545 W, and the technology, which slices the cells into several strips, is self-explanatory for its somewhat atypical cell count of 57.

As for the other module technologies combined with bifacial are half-cell and MBB, both of which are an ideal match for bifacial. Only Trina is employing a 3-cut configuration, meaning the G12 cells are split into 3 pieces instead of two for half cut cells. In line with PERC technology, the bifaciality of these products is said to vary between 65% and 75%, while Maxeon is stating a somewhat lower fixed level of 65%.

M10 bifacial modules

The second largest wafer size today is M10, which comes in 182 mm pseudo-square format, a size highly promoted by vertically integrated companies, such as LONGi, JinkoSolar, JA Solar (which all presented at the TaiyangNews 182 mm Day during the TaiyangNews High Efficiency Solar Conference in Dec. 2020, and is summarized in a special M10/182 report). However, a few cell and module companies have also opted for M10. In addition to mainstream PERC, Jolywood, for example, has adapted its TOPCon technology to 182 mm wafers. The Chinese company is offering two TOPCon module products built with 78 and 72 cells, respectively. The largest product is also the most powerful, reaching 615 W. Apart from Jolywood, 9 other module suppliers in our listing are offering modules based on M10 format commercially.

Within the PERC technology platform, GCL and Talesun are promoting the largest modules integrated with 78 cells that come with power ratings of 610 W and 590 W. With 11 products, the 72-cell configuration is the largest in our listing of bifacial modules based on M10. Nine module makers are supplying such products in 3 power classes – 550 W, 545 W and 540 W. Two products listings are from JinkoSolar and Jinergy that have the same rated power of 545 W. JinkoSolar's Tiger Pro series comes with zero gap technology called Tiling Ribbon in addition to the half cell and MBB. The others are generally using low-gap technology, another way to optimize area utilization – with the disadvantage of lower module efficiency but less process complexity and avoiding the use of special BOM. JA Solar is the only company that is promoting a 66-cell module configuration with a power rating of 505 W.

When it comes to bifaciality, TOPCon modules from Jolywood naturally score highest with 80% and 75%. The majority of the PERC product stream is rated with 70 +/- 5% bifaciality, while a few products are promoted with a fixed level of 70%.

Power Characteristics of Selected Bifacial Modules Based on M10 Wafer Size									
Company	**Product series**	**Wafer type**	**Cell tech-nology**	**No of cells**	**Technology**	**Effi-ciency (%)**	**Front power (W)**	**Rear power (W)**	**Bifa-ciality (%)**
Jolywood	JW-HD156N	n-type	TOP-Con	78 (eq.)	Bifacial, half-cell, MBB	22	615	492	80
Jolywood	JW-HT144N	n-type	TOP-Con	72 (eq.)	Bifacial, half-cell,MBB*	21.66	560	420	75
GCL	M10	Monocrystalline	PERC	78 (eq.)	Bifacial, half-cell, MBB	21.9	610	427	70
Talesun	BIPRO	Monocrystalline	PERC	78 (eq.)	Bifacial, half-cell, MBB	20.9	590	413	70 ± 5
Talesun	BIPRO	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21.1	550	385	70 ± 5
Suntech	Ultra V	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21.3	550	385	70 ± 5
JA Solar	DEEP BLUE 3.0	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21.2	550	385	70 ± 10
JinkoSolar	Tiger Pro	Monocrystalline	PERC	72 (eq.)	Bifacial, Half-cell, MBB, TR*	21.13	545	382	70 ± 5
JinkoSolar	Tiger Pro	Monocrystalline	PERC	72 (eq.)	Bifacial ,Half-cell, MBB, TR	21.13	545	382	70 ± 5
Jinergy	Mono PERC	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21.3	545	382	70 ± 5
Jinergy	Mono PERC	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB*	21.3	545	382	70 ± 5
LONGi	HiMO 5	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21.1	540	378	70 ± 5
Chint	Astrotwins	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21.1	540	378	70
GCL	M10	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21.1	540	378	70
CSI	BiHiKu6	Monocrystalline	PERC	72 (eq.)	Bifacial, half-cell, MBB	21	540	378	70
JA Solar	DEEP BLUE 3.0	Monocrystalline	PERC	66 (eq.)	Bifacial, half-cell, MBB	21.2	505	354	70 ± 10
*Transparent backsheet									

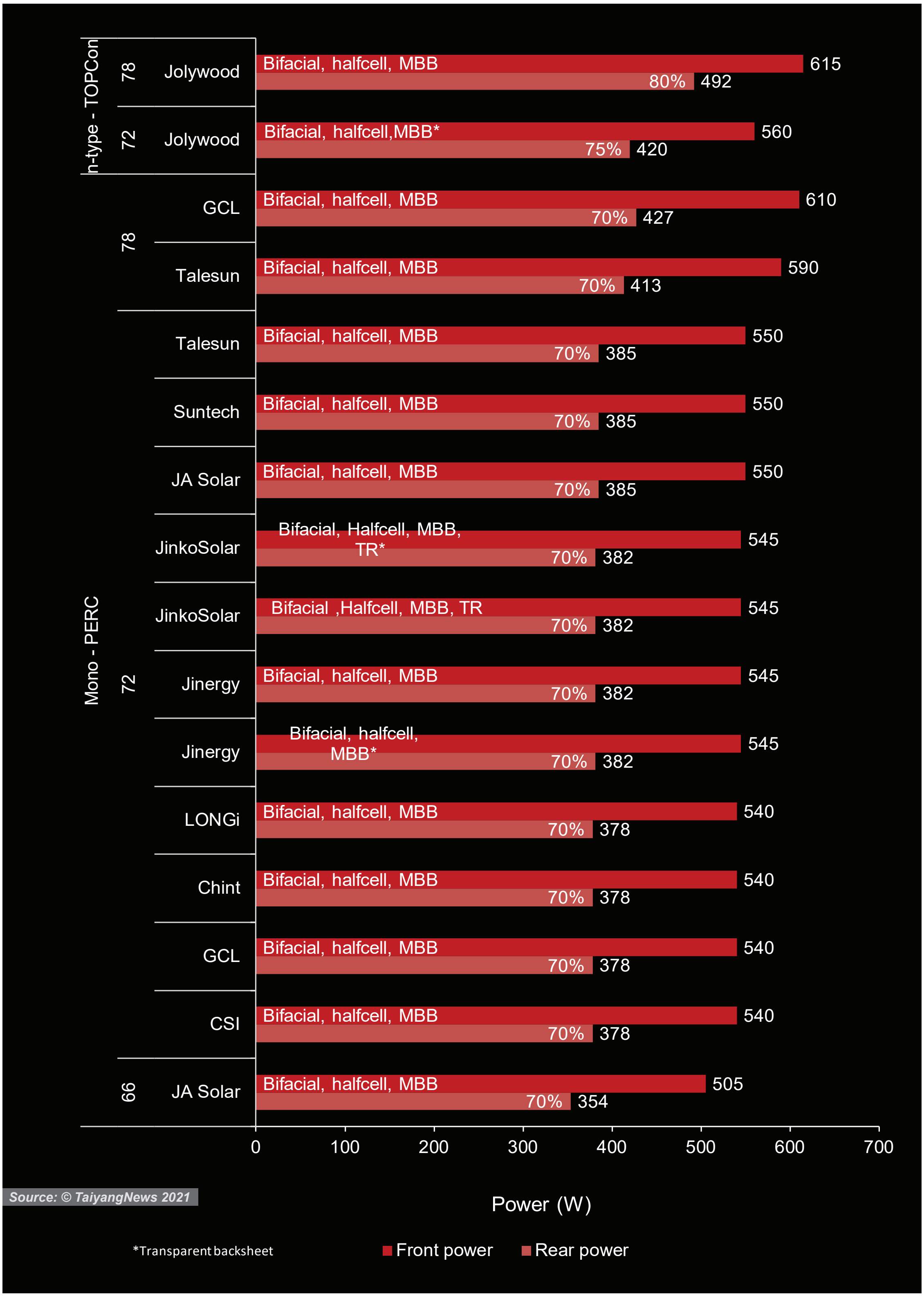
Source: © TaiyangNews 2021

M6 bifacial modules

The modules based on M6 are represented with a good cell technology mix. M6 is nothing but a 166 mm pseudo-square format, which was believed to become a standard when it was introduced in 2018. In addition to PERC, modules based on TOPCon, the first HJT variants and a few multicrystalline products are offered based on this wafer size.

However, JA Solar is offering two modules based on a somewhat atypical size of 168 mm, which are also listed here. Within the n-type category, while Jolywood is offering TOPCon modules, Jinergy is relying on HJT cells. Both the companies are offering modules in 72 and 60-cell layout. For the larger configuration, Jolywood's TOPCon product has a labelled wattage of 470 W, while Jinergy's HJT M6 panel is rated with 465 W. However, CSI is offering the product with the largest number of cells - 78, thus its BiHiKu5, a mono-PERC module comes with the highest power rating of 490 W.

Power Characteristics of Selected Bifacial Modules Based on M10 Wafer Size



Several followers: M10 or 182mm wafers, the second largest format used in module production, has gained not only several followers but even modules employing other technologies than PERC are commercially available, such as TOPCon.

The multicrystalline variant of this model has the next highest power of 475 W. The 72-cell classification M6 PERC modules contains 12 products, of which one is a multi-module. The power rating of the 11 monocrystalline products falls between 465 W and 450 W. Among the 60-cell products, one is a 380 W module and three reach 375 W. The entire listing of bifacial products are based on MBB and half-cell module technology, while two of Jinergy's products employ transparent backsheet as rear cover. When it comes to bifaciality, Jinergy's HJT modules is rated with the highest bifaciality of above 85%, followed by Jolywood's TOPCon modules at 80%. All the PERC modules featured here have an average bifaciality of 70%.

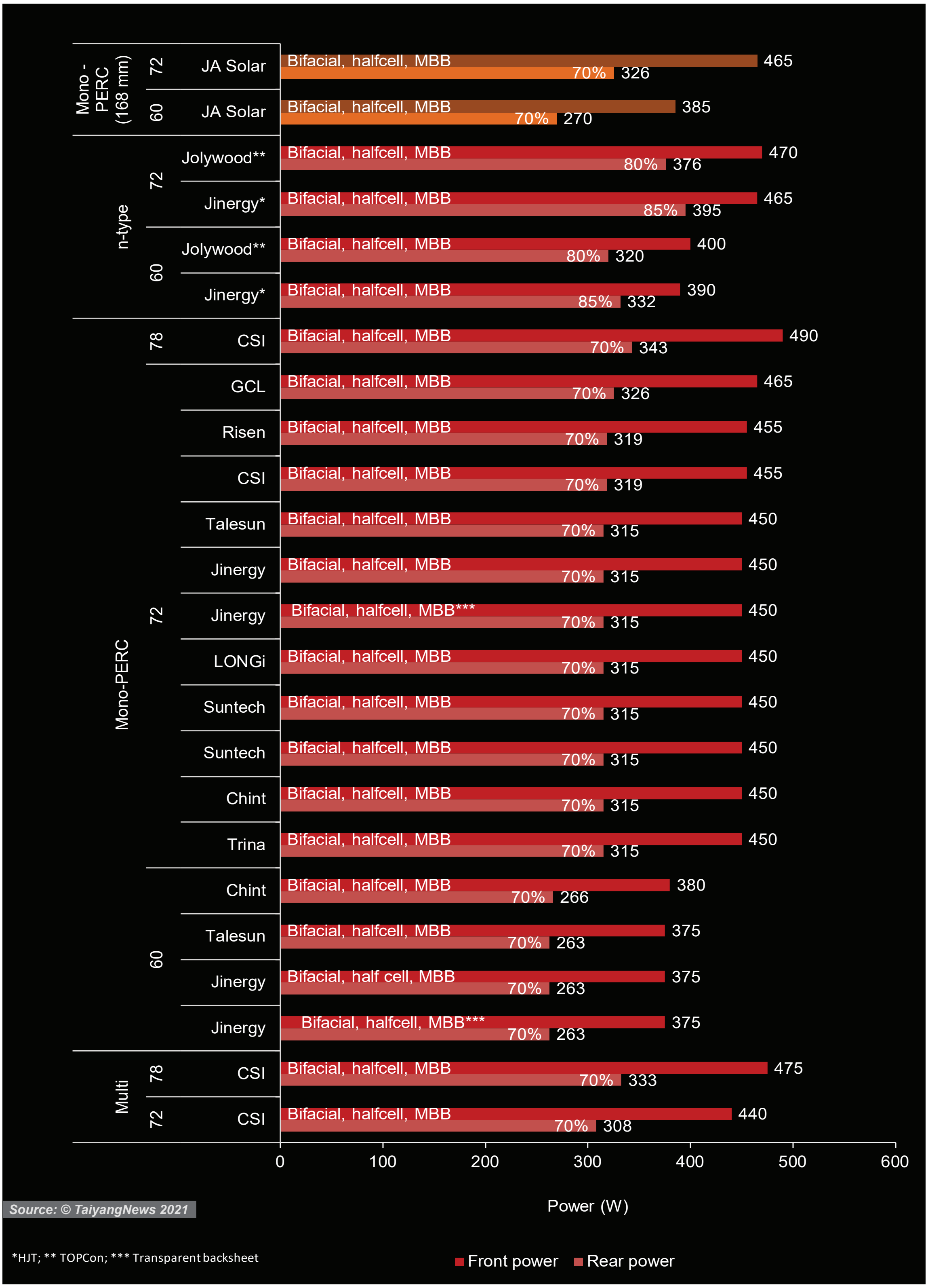
Power Characteristics of Selected Bifacial Modules Based on M6+ & M6 Wafer Size

Company	Product series	Wafer type	Cell tech-nology	No of cells	Technology	Effi-cien-cy (%)	Front power (W)	Rear power (W)	Bifa-ciality (%)
JA Solar**	-	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.9	465	326	70 ± 10
JA Solar**	-	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	20.6	385	270	70 ± 10
Jolywood	JW-HD144N	n-type	TOPCon	72 (eq.)	Bifacial, halfcell, MBB	21.40	470	376	80
Jinergy	HJT	n-type	HJT	72 (eq.)	Bifacial, halfcell, MBB	21.4	465	395	> 85
Jolywood	JW-HD120N	n-type	TOPCon	60 (eq.)	Bifacial, halfcell, MBB	21.71	400	320	80
Jinergy	HJT	n-type	HJT	60 (eq.)	Bifacial, halfcell, MBB	21.4	390	332	> 85
CSI	BiHiKu5	Monocrystalline	PERC	78 (eq.)	Bifacial, halfcell, MBB	20.7	490	343	70
GCL	M8	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.8	465	326	70
Risen	0	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.6	455	319	70 ± 5
CSI	BiHiKu	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.4	455	319	70
Talesun	BIPRO	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.7	450	315	70 ± 5
Jinergy	Mono PERC	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.7	450	315	70 ± 5
Jinergy	Mono PERC	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB*	20.7	450	315	70 ± 5
LONGi	HiMO 4	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.7	450	315	70 ± 5
Suntech	Ultra S	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.6	450	315	70 ± 5
Suntech	Ultra S	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.7	450	315	70 ± 5
Chint	Astrot-wins	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.1	450	315	70
Trina	Duomax	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.4	450	315	70 ± 5
Chint	Astrot-wins	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	20.2	380	266	70
Talesun	Bipro	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	20.5	375	263	70 ± 5
Jinergy	Mono PERC	Monocrystalline	PERC	60 (eq.)	Bifacial, half cell, MBB	20.6	375	263	70 ± 5
Jinergy	Mono PERC	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB*	20.6	375	263	70 ± 5
CSI	BiHiKu5	Multicrystalline	PERC	78 (eq.)	Bifacial, halfcell, MBB	20.1	475	333	70
CSI	BiHiKu	Multicrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	19.7	440	308	70

*Transparent backsheet; ** 168 cell size

Source: © TaiyangNews 2021

Power Characteristics of Selected Bifacial Modules Based on M6+ & M6 Wafer Size



A good mix: Modules based on M6 or 166 mm format are represented by a good cell technology mix. In addition to PERC, modules using TOPCon, HJT as well as a few multicrystalline products are counting on M6.

G1 bifacial modules

Modules based on G1 wafer size, which measure 158.75 mm per side in full-square format, was the most widely available configuration, at least by the end of 2020. We collected data of 21 modules based on G1, while Hevel's HJT module using 157.35 mm wafer size is also listed here. This group includes 5 n-type products, of which two are HJT modules from Suntech and Risen. While Suntech's product is supplied in 72-cell configuration with a power rating of 450 W and a very high efficiency of 22.1%, Risen is supplying a 60-cell format with a power rating of 355 W and an efficiency of 21%. The interesting thing here is that Suntech's module reaches a higher efficiency than Risen's product, although Suntech is sourcing its HJT cells externally. While two TOPCon modules are listed from Jolywood, India's Adani is the only supplier of an n-PERT cell based solar panel that reaches a power rating of 380 W. The p-PERC modules listed here are mainly different in terms of the number of cells integrated into the modules, which are 60, 72 and 78, with the latter being only offered by JA Solar with a power of 450 W.

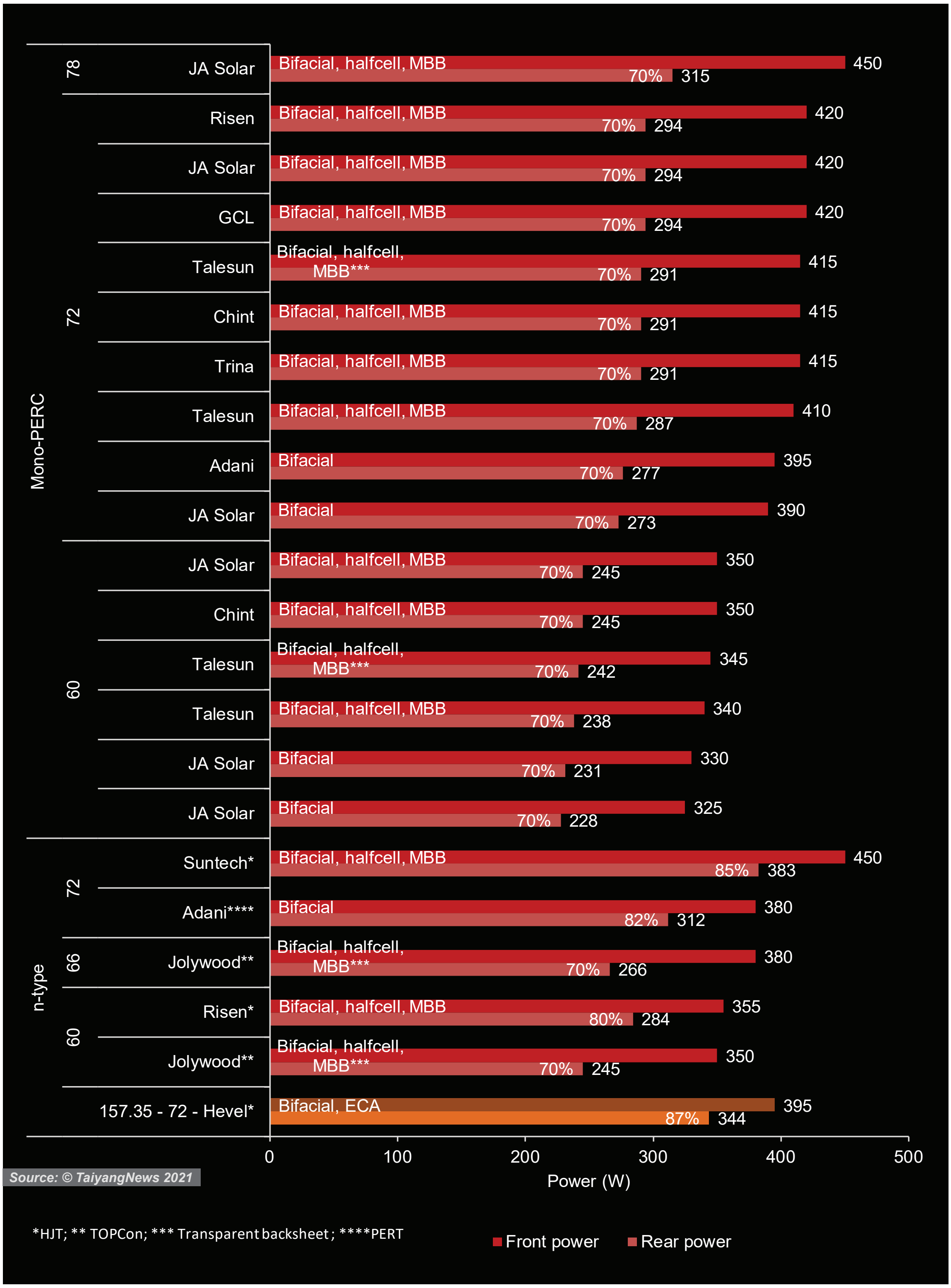
Power Characteristics of Selected Bifacial Modules Based on G1 Wafer Size

Company	Product series	Wafer type	Cell technology	No of cells	Technology	Efficiency (%)	Front power (W)	Rear power (W)	Bifaciality (%)
JA Solar	-	Monocrystalline	PERC	78 (eq.)	Bifacial, halfcell, MBB	20.4	450	315	70 ± 10
Risen	Jäger plus	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.6	420	294	70 ± 5
JA Solar	PERCIUM	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.5	420	294	70 ± 10
GCL	M3	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.7	420	294	70
Talesun	Bipro	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB*	20.28	415	291	70 + (+5~-10)
Chint	Astrotwins	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.2	415	291	70
Trina	Duomax	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20.5	415	291	70 ± 5
Talesun	Bipro	Monocrystalline	PERC	72 (eq.)	Bifacial, halfcell, MBB	20	410	287	70 + (+5~-10)
Adani	Elan bifacial	Monocrystalline	PERC	72 (eq.)	Bifacial	19.57	395	277	70 ± 5
JA Solar	PERCIUM	Monocrystalline	PERC	72 (eq.)	Bifacial	19.6	390	273	70 ± 5
JA Solar	PERCIUM	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	20.4	350	245	70 ± 10
Chint	Astrotwins	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	20.2	350	245	70
Talesun	Bipro	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB*	20	345	242	70 + (+5~-10)
Talesun	Bipro	Monocrystalline	PERC	60 (eq.)	Bifacial, halfcell, MBB	19.72	340	238	70 + (+5~-10)
JA Solar	PERCIUM	Monocrystalline	PERC	60 (eq.)	Bifacial	19.6	330	231	70 ± 5
JA Solar	PERCIUM	Monocrystalline	PERC	60 (eq.)	Bifacial	19.5	325	228	70 ± 5
Suntech	HJT	n-type	HJT	72 (eq.)	Bifacial, halfcell, MBB	22.1	450	383	85 ± 5
Adani	Elan bifacial	n-type	PERT	72 (eq.)	Bifacial	18.84	380	312	82 ± 5
Jolywood	JW-HT132N	n-type	TOPCon	66 (eq.)	Bifacial, halfcell, MBB*	20.55	380	266	70
Risen	Sieger	n-type	HJT	60 (eq.)	Bifacial, halfcell, MBB	21	355	284	≥ 80
Jolywood	JW-HT120N	n-type	TOPCon	60 (eq.)	Bifacial, halfcell, MBB*	20.79	350	245	70
Hevel**	72	n-type	HJT	72 (eq.)	Bifacial, ECA	19.8	395	344	87

* Shingling / Paving / Tiling Ribbon; ** Halfcell & Back contact; *** 3-cut & MBB

Source: © TaiyangNews 2021

Power Characteristics of Bifacial Modules Based on G1 Wafer Size



Small is still attractive: While very large wafers are the hot topic among module manufacturers, the transition cannot be accomplished overnight. Thus, a large chunk of commercial modules is still employing G1 silicon slices, which is also the case with bifacial products. This list contains 21 modules, more than for any other wafer size in this report.

The 9 modules listed in the 72-cell category come with power ratings ranging from 420 W to 390 W, whereas the power distribution range among the 60-cell modules is between 350 W to 325 W.

The G1 based products are the only segment that still includes “bifacial only” modules, in other words traditional products that don’t include any other advanced features, such as half cells or MBB. Out of the 22 listed products, 5 are purely bifacial. The PERT module from Adani falls into this category. Another unique product in terms of technology is an HJT module from Russia’s Hevel, which employs electrically conductive adhesives (ECA) for interconnection. As with the above categories, most G1 bifacial modules now employ half cells and MBB. In addition to Jolywood, Talesun is also offering bifacial modules using transparent backsheet as rear cover - each for two modules, which means 18 products are glass-glass modules. The highest bifaciality is obviously associated with n-type products. While Suntech promotes a bifaciality ranging between 80% and 90%, Hevel rates its product at a fixed level of 87%. Adani’s n-PERT module is also among the bifaciality leaders with a claimed level of 82 +/- 5%. The PERC products listed here are said to have the same average bifaciality level of 70%.

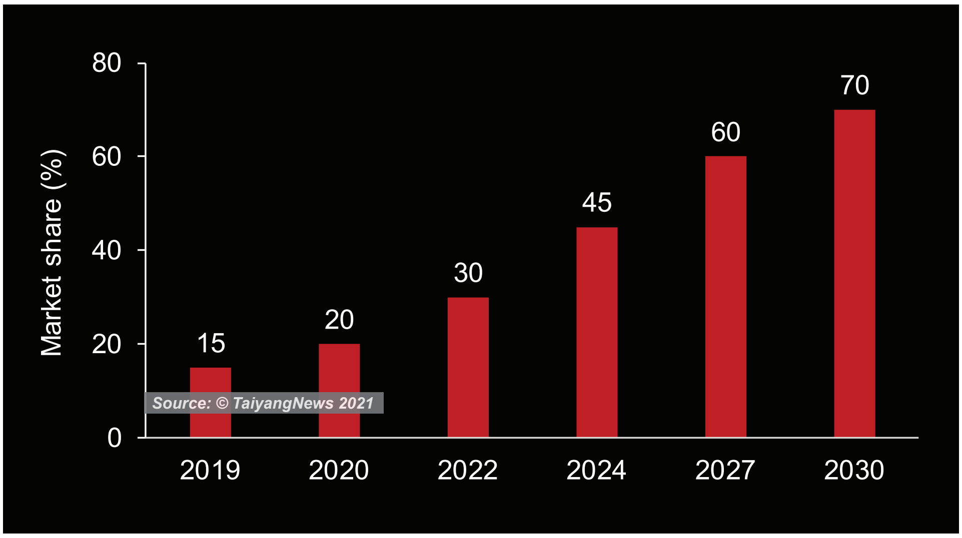
7. Bifacial Market

Bifacial solar is anything but a niche technology anymore. It has become an established mainstream module technology and is expected to only grow its share. The key facilitator for this is PERC, which has become the state-of-the-art cell technology in monocrystalline PV, and with mono's winning streak over multi also in total solar cell technology. As of today, PERC is also the most cost-effective bifacial technology. Shifting from monofacial PERC to bifacial is not cost-additive, and the switch can be done rather spontaneously, depending on demand. That means the installed capacity for bifacial PERC is, in a way, equivalent to monofacial. In fact, every advanced cell technology beyond PERC is inherently bifacial. The global capacities are to estimate, as the shift from monofacial to bifacial is effortless, and vice versa.

Bifacial is part of the technology roadmap of every leading module maker. Hongbin Fang, Director of Product Marketing at LONGi Solar, emphasized at TaiyangNews High Efficiency Conference that bifacial is one of the main routes to improve energy yield. LONGi, the world's largest fully integrated solar module producer, has deployed 10 GW of bifacial modules so far. "While bifacial accounts for about 20% of the market share in 2020, 40% of LONGi's current module shipments are bifacial," according to Fang. To help its customers adopt bifacial technology, the Chinese company has been setting up outdoor test fields in different geographical locations of the world. Every leading company is taking this approach, while the numbers may differ.

As to the question of bifacial's share in global deployment of solar modules, ITRPV estimated it to be at the same level as LONGi – that was 20% in its last year's 11th edition. Considering 2020 shipments were 135 GW, this amounts to about 25 GW. The roadmap is optimistic about the quick dissemination of the cell, estimating it to increase its share to 30% in 2022 and to take the lion's share of 70% in a decade. That means that basically all utility-scale modules and several C&I panels will use bifacial cells.

Market Share of Bifacial Cell Technology in Global Prodcut Mix - ITRPV



Striving for dominance: ITRPV expects the market share of bifacial cell technology to grow by 5% per year so that the technology will clearly dominate the cell market with a 70% share in only 10 years.

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8. Conclusions

When we published our last bifacial report nearly 3 years ago, we started our conclusions with the statement that, ‘it is impossible not to fall in love with bifacial technology, because its charm and promise are simply so enticing.’ At the time, bifacial’s share was at a low single digit level. There were quite some obstacles to overcome, but nothing looked as if it had the potential to turn into a real showstopper. We were convinced that an increasing number of stakeholders in the solar sector would feel like us. The future of bifacial solar seemed bright.

Indeed, bifacial solar hasn’t disappointed us at all. Rather the contrary. It’s impressive how quickly bifacial solar has been able to establish itself in today’s PV technology product mix after making tremendous progress in many aspects.

The advent of PERC and its quick takeover of the solar cell landscape was the kick-starter for bifacial solar’s success story. PERC is not only the most cost-effective solar cell technology today, if the production process is only tweaked at little, it turns into a bifacial cell technology basically without any additional cost compared to the monofacial variant. Despite its rather low bifaciality, the yield improvements are in many locations good enough for PERC having turned into bifacial’s working horse in the utility-scale segment. However, as the bifaciality of the different higher-efficient n-type cells is better than for PERC across the board, evolution towards these silicon species will only increase bifacial’s attractiveness. Installers will be able to pick the best bifacial technology to reach the lowest LCOE. When a site albedo is low, bifacial cell technologies such as PERC, TOPCon or even IBC might be sufficient, while locations with snow, white sand or buildings with white roofs might be better suited for the cell technology with the highest bifaciality, namely HJT.

Another proof for bifacial’s quickly growing maturity is its use with all sorts of module products. When we looked at the portfolios of the largest module manufacturers, we found nearly every latest product is also available in a bifacial variant; many even for the new large wafer-based modules. What’s helping here is bifacial technology’s flexibility enabling combination with most of the advanced module technologies, such as half cells, and at the same time optimizing the interconnection process.

On the module side, bankability was a major issue for module manufacturers and developers looking into using bifacial products. There was very little data available from system operations, but lacking almost completely from large-scale systems, even more when looking for different environments. That’s history. LONGi Solar, for example, has shipped over 10 GW of bifacial products in the last few years.

The key change needed to turn a monfocial module into a bifacial module is switching to a transparent rear cover. While glass has been the unanimous choice for bifacial panels until recently, backed by 5-year longer performance warranties than traditional modules, transparent backsheets are now also becoming a viable option. Not only is there a new generation of transparent backsheet products available from several suppliers, the first large module suppliers are offering 30 years performance warranties for their bifacial glass-transparent backsheet products. Moreover, transparent backsheets neither add to the panel’s weight nor require a change in the module BOM and processing conditions, which makes them an appealing proposition. On the other hand, glass is getting thinner to eliminate weight related disadvantages. While transparent backsheets have a window of opportunity to gain market shares as the solar sector faces a severe glass shortage, glass might come back very strong once the huge capacity expansions announced will be up and running.

Complementing the improvements of cell and modules, we have been also seeing many product innovations on the system side, which we will discuss in detail in the second part of our Bifacial Solar Technology Report to be published later this month.

There are still some issues with bifacial solar that need to be fixed, even though the situation is much better today compared to our 2018 report. One of these concerns is about the system, not on the hardware but the software side.

Although simulation software providers have worked on their programs, there is still several complaints about the accuracy of the simulation results.

Another open task is a missing fully-fledged IEC standard. However, the 2019 IEC Technical Specification (TS) is a big step forward in the field of characterization, enabling suppliers of cell testers and sun simulators to offer cell and module manufacturers products for testing bifacial PV devices in ‘standardized’ procedures. Enforcement of a final standard should not only eradicate any ambiguities in measurement but also labeling.

However, one problem that may not have an easy solution is the sales metric for bifacial modules. This will probably only be properly solved once PV projects are truly signed based on LCOE rather than $/W sales metric. We ended our last report with the statement that it’s not a question if but when bifacial solar will fully fly because its charm and promise to cut LCOEs is so enticing. Well, actually it’s flying now, having reached a 2-digit module market share in 2020 – and its attractiveness will likely make it only ‘fly’ faster.

9. Interview – LONGi

Bifacial Should Account Close To 50% Of Our Shipments

LONGi Group, with a strong foothold in the wafering business, is quickly expanding down the value chain with huge plans in place to becoming the world's largest PV module manufacturer. The Chinese vertically integrated company, which also is active in the PV power plant business, has been carrying forward the legacy of bifacial technology with several product generations. TaiyangNews talked to LONGi Solar's vice president Lv Jun about various aspects of bifacial PV technology such as bankability, module design and simulation.

LV JUN, VICE PRESIDENT, LONGI SOLAR

Dr. Jun Lv, the Vice President of LONGi Solar Co., Ltd, the adjunct associate professor of UNSW, has more than 15 years of research experience on renewable energy, environmental materials, silicon solar cell, PV module and PV system. His research expertise covers solar cell engineering and technology, solar module design, power output forecast and analysis, with research experiences in UNSW (Australia), Aalto University (Finland), National Institute of Materials Science (Japan), and Nanjing University (China).

TaiyangNews: Module manufacturers are becoming increasingly innovative; what are the advanced module technologies LONGi Solar is working on?

Lv Jun: *For LONGi, a very important product is Hi-MO 5 – a module series based on the larger M10 wafer format – which combines other advanced module technologies such as bifacial, half-cut and MBB. Hi-MO 5 is currently the main focus for us at LONGi.*

TaiyangNews: Speaking of bifacial, how important is this technology for LONGi as a technology leader in the industry?

Lv Jun: *Bifacial technology is very important for our company. In our opinion, bifacial is one technology that improves the energy yield of the PV system with minimal effort, ultimately reducing electricity generation costs from a PV system. Specifically, for LONGi, starting with Hi-MO 2, all generations of our module products have been bifacial, including Hi-MO 5 – our latest offering. Bifacial plays a pivotal role in our product development roadmap, and our journey down this path so far is proof of that. We are also cooperating with several partners, including EPC companies and PV system owners, to push and broaden the application of bifacial technology.*

TaiyangNews: There were some mixed opinions about bifacial in the past; has the technology taken off as you expected?

Lv Jun: *I can speak for the industry, not just for LONGi, when I say that bifacial as a technology is very important. As you can see, leading module makers are not only offering bifacial products, but are also vigorously promoting the technology. As for LONGi, we have shipped 10 GW of bifacial modules so far. And by our estimation, bifacial should account for close to 40% of our shipments in 2020. Globally, I estimate the application of bifacial technology in global PV deployments is more than 20%. We are now actively participating in several third-party cooperation projects to demonstrate the higher power generation of bifacial modules and to confirm the benefits of the technology.*

TaiyangNews: Bankability was one of the main concerns with bifacial, but it is not anymore. What really helped the technology to gain bankability?

Lv Jun: *Bankability does not change overnight. What we do see is that the financial institutions have started realizing the importance and advantages of bifacial technology. We are also supporting our customers and banks with relevant data that shows a noticeable gain in energy yield with bifacial systems. Bankability is especially very good in China.*

The projects awarded under the Chinese government's Top Runner program are already bankable in a way, which is probably a first step towards making bifacial bankable, like getting the snowball to roll.

TaiyangNews: When you talk about bankability, one of the important things you talk about is simulations. How accurate do you think are the current simulations right now?

Lv Jun: *Yes, simulation is indeed very important for the wider deployment of bifacial technology. As everyone knows, PVsyst has updated the software to include the bifacial function. However, PVsyst is a little conservative when estimating the gain from bifacial. As I've mentioned, we are also cooperating with several partners to generate real-time data to compare with the simulation models. We are also cooperating with research centers and testing centers and are closely involved in simulation program development.*

TaiyangNews: As a technology leader in this segment, what is your opinion about transparent backsheets?

Lv Jun: *Transparent backsheets are interesting. We are still in the process of testing it internally and would look to commercialize a product only after such material passes our stringent internal tests. As you know, we are currently relying on glass-glass configuration. In my opinion, the reliability of glass is very good, at least as of now, albeit with an increase in the weight of the modules. One way to overcome the weight issue is to use thinner glass.*

TaiyangNews: Are you also working on thin glass?

Lv Jun: *While we currently use a 2 mm glass in our bifacial modules, we are evaluating the possibility of using an even thinner 1.6 mm glass. We cannot share any information about it now, as we are still in the evaluation phase. Using a 1.6 mm glass would help keep the weight of the module at the same level as that of the glass-backsheet monofacial modules, which typically use 3.2 mm glass as front cover.*

TaiyangNews: What about the reliability of modules based on such thin glass?

Lv Jun: *It entirely depends on the size of the module. Larger modules with thin glass might face reliability issues, especially in terms of mechanical load. However, modules based on small wafer formats (M2) in 60-cell configuration can meet the requirements for mechanical loading, which means that the application of the thin glass will be restricted to smaller module sizes. On the other hand, improving the mechanical strength of the frame may even facilitate the use of thinner glasses for larger modules.*

TaiyangNews: What is the glass thickness you are using for Hi-MO 5?

Lv Jun: *We use 2 mm glass for Hi-MO 5, even for the 72-cell configuration.*

TaiyangNews: What's your opinion on frames? Can the bifacial modules go frameless or are frames necessary?

Lv Jun: *Actually, our first double-glass bifacial module was designed with a frame. However, there have been bifacial products that are frameless, especially to save on costs. But the most important aspect of a module, as important as rated power, is reliability. I have visited very large PV systems of more than 3 MW in size in Northwest China. These large solar parks have small areas built with frameless bifacial modules. I found that a majority of these modules were broken because of poor dynamic mechanical load characteristics. Frames always help in retaining the reliability of the modules. And for that reason, we at LONGi insist on using bifacial modules with frame.*

TaiyangNews: How are you accomplishing the IV characterization of your bifacial modules?

Lv Jun: *We just measure the power output from the front side. We use a non-reflective cover on the rear side. With the new IEC standard in place, we are able to label bifacial performance of our module. This is also helping our customers to confirm what products they are buying. Nevertheless, we are not selling the rear side power component to our customers. We charge a small premium for the bifacial modules, but the price metric for bifacial modules has been the front power.*

TaiyangNews: What is the average and best bifaciality you have attained in production?

Lv Jun: *While the highest bifaciality we have achieved is 75%, the average is a little above 70%.*

TaiyangNews: Thank you for the interview.

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