WHITE PAPER / **BIFACIAL SOLAR PANELS**

BIFACIAL MODULES: THERE ARE TWO SIDES TO EVERY SOLAR PANEL

Most of today's solar panels collect solar irradiance from only the front side of the panel, which faces the sun. A new generation of bifacial panels capable of capturing light reflected off the ground onto the back side of the panel may be a game changer.

Unlike photovoltaic (PV) systems that use traditional monofacial modules, bifacial modules allow light to enter from both the front and back sides of a solar panel. By converting both direct and reflected light into electricity, bifacial PV systems can generate as much as 30% more energy than a comparable monofacial system, depending on how and where the system is installed.

While bifacial module technology has existed since the Russian space program deployed it in the 1970s, it has not been commercially embraced due to the expense of producing it. A drop in manufacturing costs, however, is now leading the solar industry to give bifacial panels — and the rules for PV energy system design — a second look.

TECHNOLOGY OVERVIEW

Bifacial modules can be manufactured using either monocrystalline or polycrystalline wafers. Each solar cell in a monocrystalline bifacial panel is composed of a single silicon crystal. By giving the electrons that generate electricity flow more room to move, these panels are more efficient than polycrystalline bifacial panels, which are composed of silicon fragments that have been melted together. Production costs on polycrystalline panels, however, are typically lower than their monocrystalline counterparts.

Like all solar panels, bifacial modules receive a power rating — typically 250 to 400 watts — that represents their expected power under ideal sunlight and temperature conditions. Because this power rating considers only the front side of a solar panel, bifacial modules are also assigned a second rating for the electrical output of the module's rear side. Known as bifaciality, this ratio compares the power produced by the module's rear side to the power produced by the front, as measured during standard test conditions (STC):

$$B = P_{mpp,\ rear} / P_{mpp,\ front}$$

Today, at least nine manufacturers offer bifacial modules that have been certified for use in North America. Major manufacturers, along with their products' front-side power ratings and bifacial ratios, are listed in Figure 1.

Bifacial Module Manufacturer	Front-Side Power Rating (in watts)	Bifacial Ratio (in percentages)
Canadian Solar	365–380	70
LG	300	95
Lumos Solar	275	55
Mission Solar	320-330	(did not report)
Panasonic	190 or 225	(did not report)
Prism Solar	285-295	90
Silfab Solar	270-290	85
Sunpreme	490-510, 350-370 or 290-310	95
Yingli Solar	270-290	(did not report)

FIGURE 1: *Commercially available bifacial modules. Source: SolarPro 2017.*

While a bifacial ratio has value, it is not necessarily a good indicator of a bifacial PV system's performance in the field, which is highly dependent on everything from its geographic location to the time of day. To optimize bifacial energy efficiency and yield, for example, bifacial arrays can be installed above light-colored surfaces that reflect as much light as possible. They can also be raised and tilted in ways to collect more reflected light and avoid shading their rear sides. Solar tracking systems can also help to maximize electricity production by rotating solar panels to follow the sun throughout the day, optimizing the angle at which panels receive solar radiation. In addition, tracker manufacturers may adjust the typical tracking schemes to account for bifacial modules, such as reducing the amount of backtracking or adjusting mid-day positions. Studies conducted by PV module manufacturers, according to SolarPro, have shown energy yield increases of up to 11% for fixed tilt systems and 27% for tracker systems, when compared to similarly rated traditional modules.

BIFACIAL MODULE CONSTRUCTION OPTIONS

Bifacial module manufacturers have two primary ways of constructing a bifacial cell. Some encapsulate both sides of the cells in a layer of solar glass. Others use glass on the front and a transparent polymer-backsheet material on the back.

More manufacturers today are opting for the dual-glass approach, which tends to be more durable in the field, compared to glass-on-polymer options. Dual-glass solutions are also more rigid and less water permeable, which helps safeguard them during handling and installation, as well as protect them from wind, rain, snow and other environmental conditions. They historically have lasted longer and had lower failure rates than polymer-backsheet alternatives. Many manufacturers offer longer warranties on dual-glass modules as a result. According to *Solar Power World*, this durability results in a lower annual degradation rate (in the range of 0.5% per year for dual glass versus 0.7% per year for polymer-backsheets), which directly impacts lower levelized cost of energy (LCOE).

Material manufacturers, meanwhile, are working to help polymer-backsheet modules keep pace by developing solutions that offer other advantages. DuPont, for example, has released transparent bifacial module backsheets with a white grid that allows extra reflectivity between the cells, resulting in higher power output. Other designs provide electrical insulation while also sealing the modules from moisture, ultraviolet (UV) light and other outside elements. Polymer-backsheet modules also tend to be lighter and easier to transport and install, and they have been shown to reduce the potential induced degradation (PID) sometimes associated with dual-glass systems.

INCREASING BIFACIAL MODULE ENERGY PRODUCTION

While bifacial module technology increases energy production, a variety of factors can affect the rate of this increase. Among the most critical factors to consider when predicting bifacial module yield are module mounting height and albedo, or the fraction of light reflected by the surface.

Module mounting height — The closer a bifacial PV array is to the ground or a roof surface, the less chance reflective light will reach the back of the array. A significant bifacial energy boost is possible, however, with a relatively modest height increase. In one simulation, the energy boost curve was steepest between 0 and 7.9 inches. After about 20 inches, the curve flattened out and additional energy gains were negligible. This data from *SolarPro* suggests that bifacial modules are appropriate for most ground-mounted applications, given that the leading edge of these arrays is usually from 18 inches to 36 inches above grade.

Modeling bifacial modules to predict their increased energy production, however, continues to be a combination of art and science. PVsyst, a software program used to study PV systems, has limited modeling capabilities, with module manufacturer and user inputs remaining a critical part of the modeling process. Currently, hand calculations are typically needed to compute the equipment shading factor. Extra modules and cell mismatches are, at this point, also largely a judgment call by the installer.

As long as inputs are accurate, however, software modeling results tend to be relatively accurate. Field testing is needed to verify these results. Keep in mind that a 10% error on the back-of-module calculation can result in a 1% error in annual production, according to *SolarPro*.

Albedo — Annual energy production increases of 5% to 10% are typical with bifacial modules. In most areas, imported groundcover is often needed to push the increase much over 10%.

The question is, does it pay to bring in light-colored gravel or roofing to control albedo? The answer to this question is both location- and project-specific, and a cost evaluation is needed to make the final determination. The estimated albedo for various surfaces is outlined in Figure 2.

Surface Type	Albedo (by percentage)
Green filed (Grass)	23
Concrete	16
White painted concrete	60-80
White gravel	27
White roofing metal	56
Light gray roofing foil	62
White roofing foil (for solar applications)	>80

FIGURE 2: *Albedo values of certain ground surfaces measured with test setup. Source: SolarWorld.*

IMPACT OF BIFACIAL MODULES ON PV SYSTEM EQUIPMENT AND OVERALL DESIGN

The use of bifacial modules can impact PV system equipment and design in significant ways. Conventional racking systems for monofacial modules include rails that cross the rear side of these panels. To optimize energy gains in bifacial PV systems, designers need to find ways to avoid or minimize elements that create shade on the rear side of modules. Rails and other structural components can also cover cells, which can lead to hot spots that can damage modules.

To avoid these issues, bifacial PV systems require special mounting systems. Those optimized for bifacial applications typically have narrower mounting rails in their racking and tracker structures. Strategically placed vertical supports are also typically designed to minimize back-of-module shading.

Likewise, the junction box on many monofacial modules is located directly behind one or more PV cells. By contrast, most bifacial modules typically are designed to have smaller, low-profile junction boxes located at the perimeter or on the backs of modules.

In a December 2018 white paper, “Bifacial vs. Silicon Modules on Genius Tracker,” GameChange Solar takes a deeper dive in addressing optimal mounting configurations for bifacial modules. The paper argues that mounting modules two-up in a landscape layout helps to minimize degradation. Modules mounted one-up in a portrait configuration, though, produce better financial performance. Actual field results, however, may vary, based on racking and tracker design. In these cases, PV system designer and end users should coordinate with the racking and tracker vendor for bifacial module design, equipment selection and the most effective tracking scheme.

Along with these considerations, multiple other features should be considered in design. Some bifacial modules, for example, are designed with a gap between cells mid-module to minimize cell shading. Modeling efforts should address whether an increase in row spacing is needed or should be suggested.

Height of the tracking system should be optimized, as extra energy production can result when torque tube height is increased.

As power output increases due to the use of bifacial modules, so should cable and overcurrent protection, as well as electrical equipment ratings. Cables and equipment should be sized to handle the maximum currents listed in the PV module data sheets, which may increase some balance of system (BOS) equipment sizes and costs. Higher energy output also has the potential to impact the life of PV inverters. System designers should coordinate with inverter manufacturers to help make sure additional direct current (DC) power generated by bifacial modules will not exceed the ratings of the inverter components or recommended DC/AC ratios. This is a common way of representing this variable in PV design.

Additional considerations will also need to be accounted for when estimating operation and maintenance costs. For example, it is necessary to factor the cost of cleaning the rear sides of bifacial modules into regular maintenance budgets. Also, vegetation and site management may be more frequent and more involved to maintain higher albedo of the ground around bifacial arrays.

COST-BENEFIT ANALYSIS AND A LOOK TO THE FUTURE

Bifacial PV systems offer many advantages over traditional systems. The performance gains achieved through increased light collection are just the beginning. Bifacial modules also have lower BOS costs, since fewer modules are needed to produce the same amount of energy as traditional modules. These systems require a smaller array footprint. They're also more durable, in many cases, because both sides are UV-resistant and PID risks are reduced.

Taken together, the energy gains and improved durability of bifacial PV systems result in improved production and performance over the systems' lives. They take a major step forward toward the ultimate goal of a lower LCOE. Such LCOE analysis for bifacial modules, however, is still in its early stages, with the development of uniform measurement standards still in process.

Ultimately, more bifacial module installations and real-world data are needed to tell the story of this technology's future. Both are needed to verify the benefits and justify the additional costs of bifacial through LCOE analysis, which should become possible in the relatively near future.

Once standards are tightened and LCOE is quantified and proven, it is likely that bifacial modules will become the norm for utility-scale installations. The time to take a closer look is now.

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