KIPP & ZONEN

BIFACIAL PHOTOVOLTAICS ON THE RISE

GUIDE

Overview of Market Situation and Current Research

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See you on the other side

During the last two decades, photovoltaics (PV) has matured as a technology with a low probability of spectacular efficiency increases. Lowering levelized costs of energy (LCOE) is now achieved rather by shrinking investment and operating costs than by enhancing energy output of PV cells through technological progress.

However, one promising way to significantly boost the efficiency of PV cells is to use the rear side of the modules for electricity generation, too. Thus, reflected or diffused sunlight is added to power generation without extending the footprint of a module.

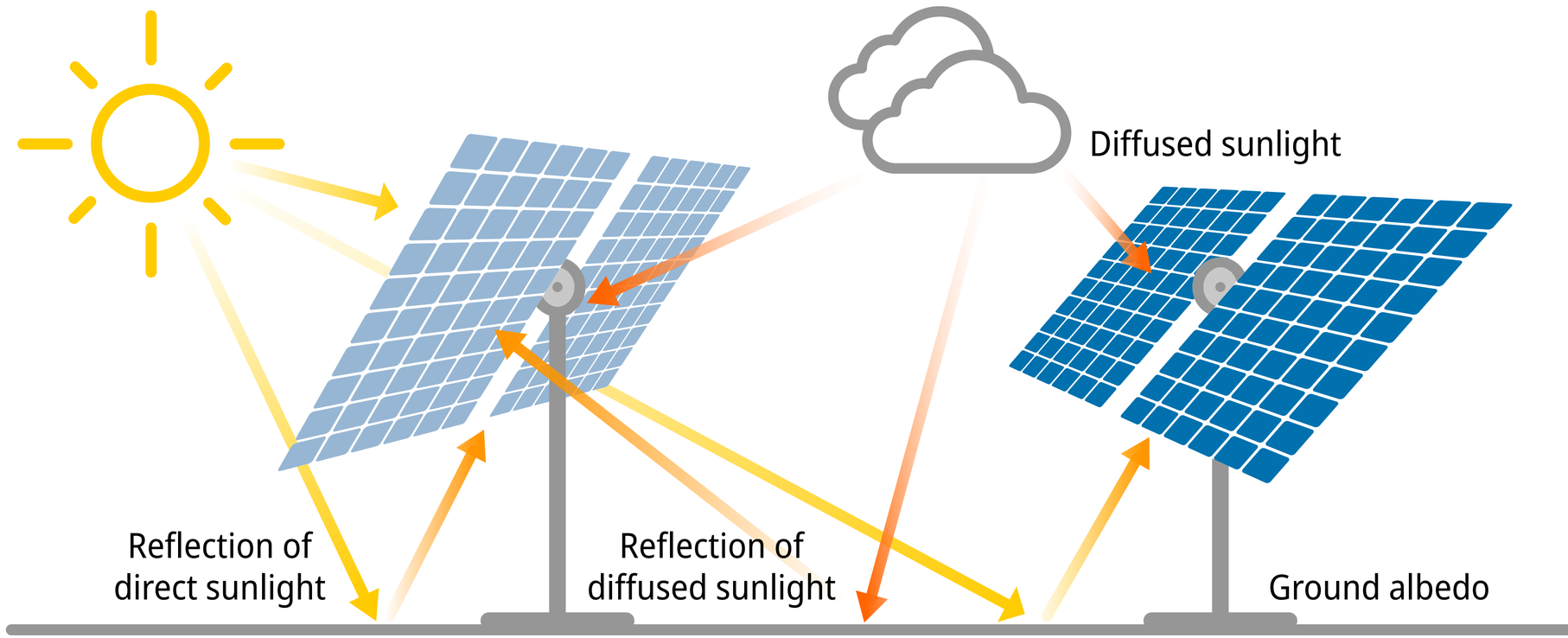
There seems to be a consensus on the high potential of bifacial PV. However, in the absence of widely established methods to both simulate and measure energy output gains, predictions of efficiency increase through bifacial PV modules vary considerably; this being dependent upon the assumed system setup, the location, surface albedo, the implemented simulation algorithm and further criteria.

What is bifacial PV?

Bifacial PV is slowly finding its way to becoming mainstream by surpassing global energy capacity of Gigawatts of produced energy. With that, a growing basis of collected data on module performance will help to predict efficiency gains more precisely. In this article, we try to give an overview over current research, unanswered questions and technical developments in the bifacial world.

How bifacial photovoltaics work

The main idea is simple. Instead of collecting sun rays on only one side of a PV module, the rear surface catches reflected and diffuse light coming from several angles to generate more electricity. Separate from adjustments regarding rear side material and interconnection, cell technology and geometry base upon proven principles of monofacial modules. That said, bifacial PV is likely to alter smoothly from a promising vision to a widely applied technology with an estimated world market share of up to 30 to 50 per cent within the next ten years.



Bifacial PV – the sleeping giant of the industry

Although bifacial PV cells have already been researched and developed in the 1960's, their broad use has yet to come. A common explanation by market observers is the lack of precise calculation methods for yield gain compared to monofacial systems. For this reason, investors proceed to act carefully, yet hesitate to push bifacial systems on a larger scale in due part to limited knowledge of accurate efficiency increases. Even in the age of big data and machine learning, simulation of solar irradiance on the rear side of modules is a complex task. Therefore, companies and institutions around the world continuously investigate a variety of potentially relevant parameters and their impact on the energy output.

Those research projects cover, among other criteria:

- Impact of ground albedo
- Material of the back sheet
- System setup and module geometry
- Measuring solar irradiance on the backside

System setup & module geometry

Contrary to monofacial PV modules, where sun beams being converted to electricity come mainly directly from the sky, the rear side of bifacial modules gathers light that has found its way through a labyrinth of shadows, ground texture and construction obstacles. However, optimizing the amount of solar irradiance on one side can negatively affect the performance on the other. Therefore, finding the ideal setup for bifacial PV plants is a complex challenge. While the tilt angle is a vital factor for module efficiency, the ideal angles for the front and back sides can vary.

Another parameter is the length of modules and the distance between the module rows, resulting in the ground-coverage ratio (GCR). Traditionally, a high GCR adapted to the incident angle of the sun beams increases the efficiency of a plant. However, even for monofacial PV plants, a higher GCR can cause intershadowing at lower solar altitudes in the morning or evening hours. On bifacial plants, shadowing becomes an even greater issue. Ideally, there is enough space between the module rows to have a preferably large surface for ground reflection that is not covered by shadows. In turn, this decreases ground-coverage ratio and plant output per area as well.

Further parameters regarding module setup comprise the construction height and the torque tube. Because the torque tube is for tracking PV modules, bifacial modules are placed higher in order to convert more light reflected from multiple angles of the ground; resulting in higher construction costs. The same concept applies for a modified torque construction with the objective of avoiding shadowing through mounting parts.

Impact of surface albedo

Most of the light reaching the rear side of a PV module is reflected from the ground. Reflection properties vary significantly in regard to the ground surface material, structure and color. Ideal back-of-module conditions would exist of a white ground surface, e.g. snow or a white foil. Efficiency increases significantly compared to a monofacial setup. It is unlikely that the loss due to a cloudy day can be compensated by a bit more energy from the back. In contrast, dark soil (absorption) or wet grass (scattering) can limit the impact on rear side irradiance. Renowned institutes like the US National Renewable Energy Laboratory or German Fraunhofer-Gesellschaft investigate the influence of various kinds of surfaces on rear side irradiance.

Material of backsheet

It is clear that a bifacial PV module has to have a transparent backsheet. However, when it comes to the material, different ideas vary within the industry. Modules with glass sheets on both sides, also called glass-glass, are believed to be cheaper than modules with a transparent synthetic backsheet (single-glass). With new developments and growing production capacities, this could change. Thus, single-glass modules could provide attraction to solar plant operators by being lighter (around 9 kg for a module) and more convenient to install. Several open questions weigh the longevity of both construction types.

Valid measurement of rear side irradiance

As the paragraphs above show, predictions of rear side irradiance are complex. In order to calculate potential benefits of bifacial plants, simulations must improve and gain precision. The only way to verify their quality is to measure the actual irradiance with proven and reliable instruments. Ongoing discussions continue on which type to use and where to place them. Therefore, several organizations and we as a producer of pyranometers, work on research to evaluate the ideal setup for reliable measurements.

Our research

Kipp & Zonen produces an albedometer which can measure the front and backside irradiance quite accurately. However, for the measurements it matters where the mounting position within the PV plant is. In order to gain insight into which mounting position is most beneficial, we have performed a simulation study using NREL developed software: Bifacial Radiance.

The effect of different positions on the rear side of the PV module, various places within the PV plant, as well as multiple albedo numbers are investigated. A position at which the measured irradiance represents the average irradiance on the panels is at roughly 60% height of the complete structure. The results of the simulation will be validated using multiple sensors on our test site.

For now, based on our experience and research as well as looking at current trends in the industry, we consider two sensible ways to measure solar irradiance on a bifacial parc.

1. Using Plane Of Array (POA) sensors on the front and the rear side of the module

2. Using a combination of sensors on the front side, consisting of POA, Global Horizontal Irradiance (GHI) and an albedometer, to calculate the POA on the rear side with a suitable software

“Which way the industry goes, is not fully clear. Further research is needed to investigate the optimum method to measure back side irradiance.”

Dr. Marc Korevaar - Scientist - Kipp & Zonen

Conclusion

All of the signs note that bifacial photovoltaic modules will become prevalent as an established alternative to conventional monofacial modules. However, regarding some technical and geometrical limitations, they will not fit into every project and application. Intershadowing, laborious maintenance and surface-dependent performance are just a few challenges to be considered.

Furthermore, there are still many unanswered questions regarding the optimum setup of bifacial modules. This includes the fundamental parameters such as module size and height, row length and distance, surface structure, tilt angle and much more. While numerous specialized companies and renowned research institutes are investigating these questions, the industry will work to gain a better understanding of how to tap into the full potential of bifacial modules in the near future. As an experienced and trusted manufacturer of pyranometers, we are taking our part in this. Kipp & Zonen is working on methods and setups for measuring solar irradiance for bifacial plants at the highest accuracy levels.

Without a broad and reliable data basis, plant operators will never know if their equipment is performing according to standard. What is more, investors are waiting for accurate predictions of potential efficiency increase when choosing bifacial modules instead of monofacial ones. Important decisions consistently require meticulous facts and figures. Gathering trustworthy data is crucial for that.

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