Why diffuse irradiance is key for bifacial PV systems

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As utility-scale PV plants face increasing pressure to maximize energy yield, minimize grid imbalance to avoid financial penalties and meet performance guarantees, the precision of irradiance measurements has become more critical than ever. The accrued wisdom of decades suggests that accurate irradiance measurement is not merely advantageous, it is essential. While parameters such as Global Horizontal Irradiance (GHI) and Plane-of-Array (POA) irradiance are often monitored, the less-explored variable of Diffuse Horizontal Irradiance (DHI) poses a critical oversight in PV performance metrics. For plant operators, EPCs and asset managers, relying on estimated DHI is no longer just a technical shortcut, it's becoming a growing operational and financial liability.


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Why DHI deserves attention

Unlike global irradiance, which includes both direct sunlight and scattered light, diffuse irradiance accounts only for the portion of sunlight that has been scattered by the atmosphere and reaches the surface indirectly. That distinction matters considerably, especially in real-world conditions where clouds, haze and atmospheric particles reshape the solar resource.

Today's PV systems, particularly those with bifacial modules and single-axis tracking, rely heavily on diffuse sky radiation. Under high-latitude climates, winter conditions, or cloudy skies, diffuse irradiance can account for 60% to 90% of total irradiance, and can exceed 95% under fully overcast conditions.

Bifacial PV systems on single-axis trackers typically deliver 5% to 15% more energy than monofacial systems. The exact gain depends on factors like ground reflectivity (albedo), tracker height, row spacing (pitch), and the fraction of diffuse irradiance. Under optimized conditions, such as high-albedo surfaces, elevated mounting, and low soiling, the gain can exceed 15%.

DHI contributes significantly to bifacial gain, especially in climates with high cloud cover or atmospheric scattering. Unlike direct irradiance, which mainly hits the front side of the module, diffuse irradiance reaches both sides of a bifacial panel due to its multi-directional nature. When a bifacial panel is mounted on a single-axis tracker, the rear side can capture reflected and scattered light from the ground and surrounding environment, even while tracking the sun.

In these systems, the tracker often shades part of the rear side from direct sunlight, making diffuse and ground-reflected light essential contributors to rear-side energy capture. Therefore, accurately measuring DHI and albedo is crucial for performance modeling and monitoring of bifacial PV systems with trackers, helping ensure that bifacial gains are properly understood, forecast and optimized.

Despite this, many systems continue to use decomposition algorithms to estimate DHI from GHI, introducing significant modeling error (Ineichen, 2011). Energy yield predictions are inherently uncertain, shaped by factors such as location, array tilt, and sky variability. Among these, irradiance data is a primary source of error, often contributing to a total uncertainty of 5 to 15% in long-term projections.

In utility-scale PV systems, even a modest 1% deviation in expected yield can translate into financial impacts of tens of thousands of euros per megawatt each year (IEA, 2020). This can be especially relevant under diffuse sky conditions, where traditional assumptions about solar exposure may no longer hold. By using accurate diffuse irradiance measurements on site, operators can fine-tune PV tracking strategies, adjusting tilt and orientation to better capture scattered light. When diffuse conditions dominate, flat or fixed-tilt positions often outperform sun-tracking configurations, making real-time or seasonal adjustments critical to maintaining optimal performance.

Closing the DHI gap

In most PV systems, in-plane irradiance is typically measured using sensors mounted on the front side of the modules. In bifacial systems, additional sensors are installed on the rear side to measure the contribution of diffuse and ground-reflected irradiance, enabling a more complete assessment of total energy input. But on utility-scale sites, covering every array or tracker is costly, and rear-side irradiance is anything but uniform. That's why many operators rely on modeling approaches, such as view-factor or ray-tracing simulations, that incorporate albedo, diffuse irradiance and array geometry to estimate rear-side irradiance in bifacial PV systems. It's efficient, but only as accurate as the data behind it, making high-quality DHI and albedo measurements more essential than ever to ensure the bankability of the project's energy yield estimates.

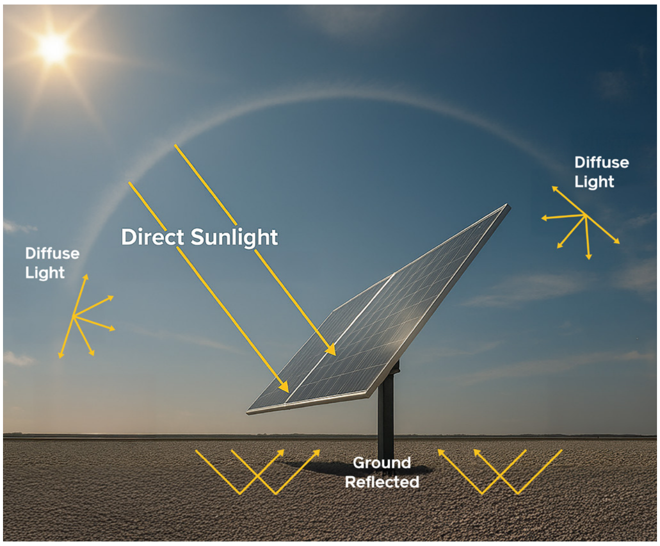
While sun tracker–based measurement systems deliver the most accurate and bankable DHI data, their high cost and complexity often put them out of reach for many sites. Satellite-based estimates offer broader spatial coverage, but with large uncertainty in instantaneous values, their precision falls short, especially under fast-changing sky conditions.

For projects that demand reliable, high-frequency data, ground-based DHI measurements strike the best balance between accuracy, practicality and long-term value. Simplified DHI sensors offer a more affordable option for ground-based measurements, but their accuracy, consistency, and traceability can differ widely depending on the design and implementation.

The EKO MS-80SH Plus solar monitoring station bridges this gap, delivering high-precision, spectrally flat pyranometer-based DHI measurements with full compliance to the ISO 9060 Class A and IEC 61724-1 Class A standards. With unprecedented 5-year long-term stability, ideal for reliable energy assessments and performance validation in utility-scale PV projects.

How the MS-80SH Plus works

The MS-80SH Plus system addresses these challenges through direct, physical measurement of GHI, DHI, and DNI. It pairs an



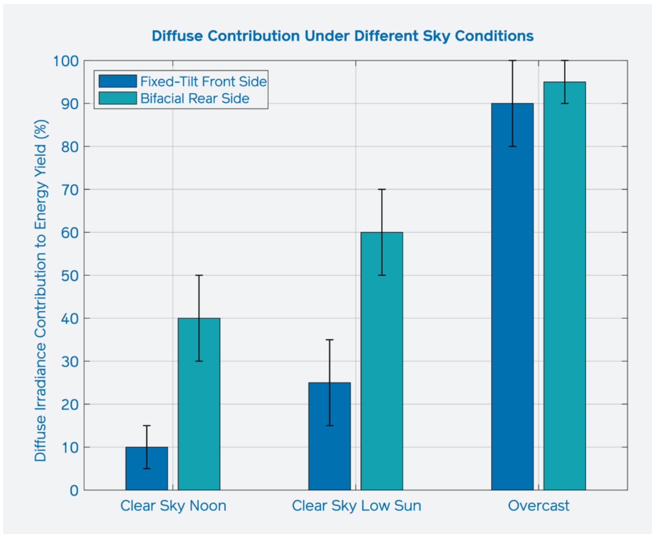


Figure 1: Left, Irradiance contributions in Bifacial PV Arrays; Right, Distribution and diffuse irradiance contribution to PV energy yield under different sky conditions. Error bars reflect typical variability due to sky conditions and array geometry

ISO 9060:2018 Class A pyranometer (MS-80SH) with a motorized rotating shadow band (RSB-02), allowing the system to dynamically shade and un-shade the sensor in alignment with the sun's position.

The sensor features a flat spectral response from 285 nm to 3000 nm and fast thermopile response time, delivering accurate performance across all sky conditions and PV technologies.

In addition, the system supports Tracking Shading Band (TSB) mode, which enables continuous DHI measurements throughout the day. Unlike traditional fixed-interval shading methods, TSB mode continuously adjusts the shadow band in sync with the sun's path, maintaining optimal shading of the sensor.

This approach improves the accuracy of diffuse irradiance measurements, especially under variable sky conditions, cloud movements, and low sun angles, offering a more reliable data set for system performance evaluation, yield modeling and bifacial energy gain analysis.

Designed for utility-scale reliability

The MS-80SH Plus system is built for long-term, reliable use in remote or harsh environments. A direct-drive motor enhances durability by eliminating mechanical wear and includes a built-in encoder for precise motor positioning. The pyranometer monitors both sensor tilt and internal humidity, and features built-in dome heating to prevent dew and frost formation, ensuring stable and accurate measurements under changing weather conditions.

Furthermore, the smart C-Box controller includes GPS, for precise solar position determination, and supports Modbus RTU, allowing seamless integration with SCADA systems, centralized data loggers or standalone monitoring setups.

The system operates in two flexible modes.

In Rotating Shadow Band (RSB) mode it performs a complete irradiance cycle every 15 seconds, measuring GHI, DHI and DNI. An optional downward-facing pyranometer allows for measurement of Reflected Horizontal Irradiance (RHI) and real-time albedo measurement.

In Tracking Shadow Band (TSB) mode the system provides continuous 1 second DHI monitoring. A secondary upward-facing pyranometer can also be integrated to support simultaneous GHI and DNI data output.

Field deployments confirm the system's high performance across varied conditions. Results show typical measurement performance of less than ±5% deviation from high-end sun tracker-based systems, even under variable sky conditions.

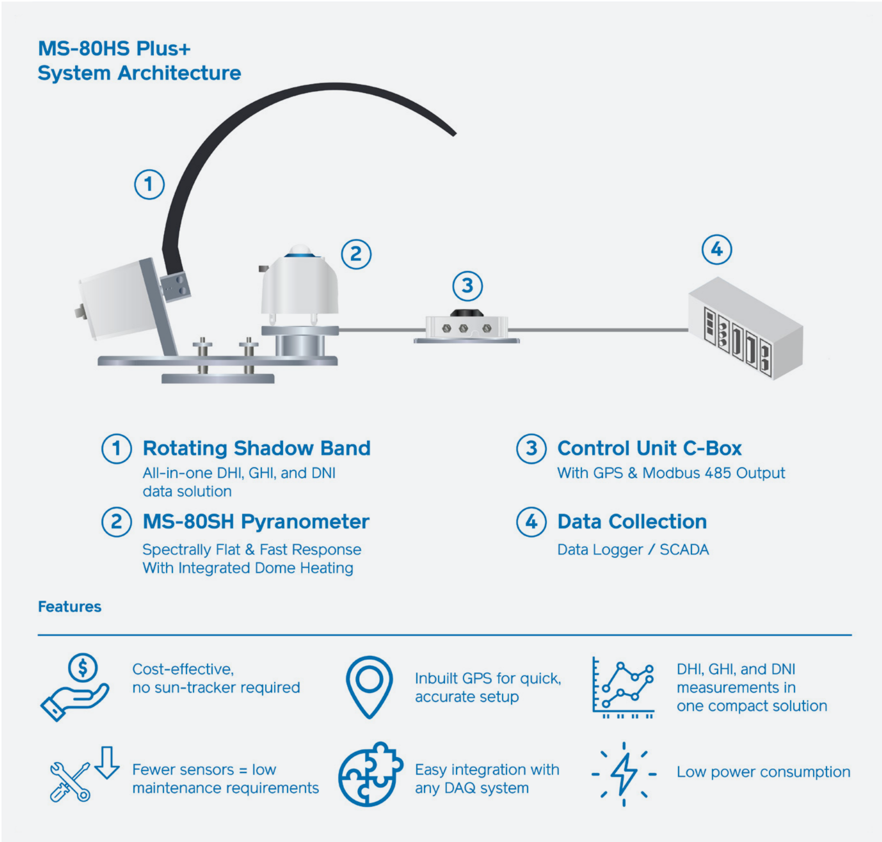


Figure 2: MS-80SH Plus system architecture: the Class A sensor, rotating shadow band and the intelligent C-Box controller with integrated GPS and Modbus RTU output

Addressing industry trade-offs and hidden costs

Several simplified DHI solutions have entered the market in recent years. Fixed-mask sensors approximate DHI by shading part of the sky dome using geometric cutouts. While mechanically simple, their accuracy strongly depends on solar position and atmospheric conditions.

Measurement uncertainty can exceed ±10%, especially under cloudy conditions, making their performance in those cases comparable to that of satellite-based DHI estimates. Other instruments use multi-element arrays or silicon detectors to reconstruct diffuse irradiance. These systems often require proprietary correction factors and calibration procedures, reducing transparency and traceability to the international ISO 9060 standard for solar irradiance sensors and IEC 61724-1 standards for PV monitoring.

Spectral accuracy

Some instruments are described as spectrally matched to PV modules due to their use of silicon sensors. While this can offer reasonable alignment under clear-sky conditions, it's important to understand that different PV technologies have varying spectral responses. As a result, this matching is not universally accurate.

Furthermore, under changing atmospheric conditions, such as cloudy skies or low solar angles, silicon sensors can experience spectral mismatch, leading to measurement errors of up to 5% and reduced reliability in performance assessment (King et al., 2004).

Spectrally flat sensors, such as thermopile-based pyranometers, overcome these limitations by maintaining a consistent response across a broad wavelength range (typically 285–3000 nm), regardless of sky conditions. This ensures accurate, technology-independent irradiance data that can be reliably used for evaluating a wide range of PV module types and environmental conditions, critical for long-term performance analysis and bankability assessments.

Calibration traceability

Another often overlooked cost in most alternative systems is the need for specialized indoor calibration, which is frequently unavailable in many regions. Many of these instruments depend on factory-tuned algorithms and do not comply with international standards.

In contrast, the MS-80SH Plus system features an ISO 9060:2018 Class A pyranometer, which can be calibrated using widely accepted ISO 9847 procedures, allowing recalibration at ISO 17025 or non-certified laboratories around the world.

From modeling and forecasting to performance ratio assessment and bifacial optimization, DHI plays a central role in plant performance, profitability and operational risk.

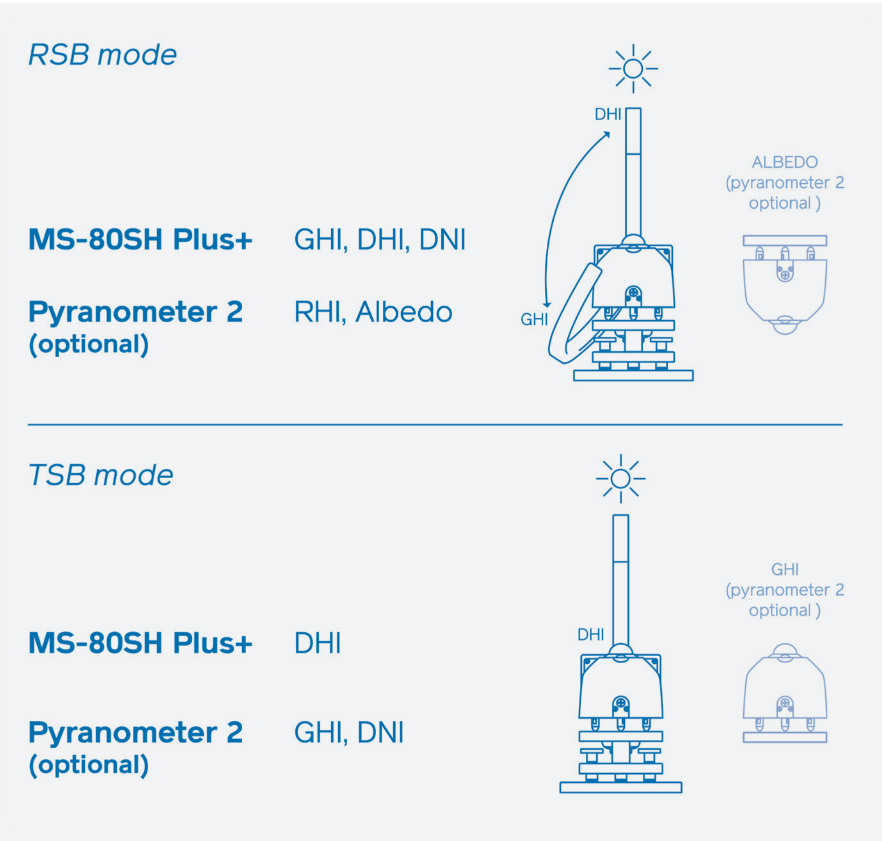


Figure 3: MS-80SH Plus operating modes. RSB mode provides GHI, DHI, and DNI, with optional RHI and albedo from a downward sensor. TSB mode delivers continuous DHI for real-time monitoring, with an optional upward sensor for GHI and DNI

Simplifying long-term maintenance and lowering operating expenditures by using an ISO 9060 Class A pyranometer that is one of the requirements to achieve an IEC 61724-1 Class A monitoring system.

The bottom line

In the evolving solar landscape, measuring diffuse irradiance accurately is becoming increasingly indispensable. From modeling and forecasting to performance ratio assessment and bifacial optimization, DHI plays a central role in plant performance, profitability and operational risk.

While traditional sun tracker systems and shadow rings with ISO 9060 Class A sensors have set the standard for accurate DHI measurement, they are often costly and impractical for widespread deployment.

Simplified sensor alternatives may offer ease of use, but they fall short in meeting the stringent requirements for compliance, traceability, accuracy and long-term data integrity; standards that are essential for today's utility-scale PV systems and performance validation.

The MS-80SH Plus+ system now offers a compact and fully compliant alternative. Outside of these solutions, no other commercially available systems provide true Class A performance for DHI measurement. For accurate, traceable, and bankable diffuse irradiance data, especially critical in bifacial and advanced PV applications.

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Further reading:

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