From clouds to kilowatts: illuminating PV potential with diffuse irradiance insights

Accurate solar irradiance data is crucial for designing, operating, and maintaining solar photovoltaic (PV) systems. Solar projects use various methods to gather this data, including Typical Meteorological Year datasets, satellite estimates, and ground-based measurements. The latter provide detailed insights for planning and monitoring. Instruments like pyranometers and pyrheliometers measure irradiance to optimize solar systems. Innovations like EKO's MS-80SH Plus+ system add precision to solar irradiance monitoring, highlighting the importance of diffuse irradiance in solar energy applications. Because having the right data, whether in clear or cloudy conditions, ensures optimal solar energy harnessing.

Accurate data on solar irradiance plays an indispensable role in assessing solar resources, quantifying the effectiveness of Solar Photovoltaic (PV) technologies and throughout the lifecycle of PV systems. It guides decisions in design, certification, operation, maintenance, and troubleshooting.

The approach taken for the evaluation of solar resources varies depending on the scale and phase of solar projects, requiring tailored approaches. At each stage, from conception to operation, distinct methodologies, including the use of Typical Meteorological Year (TMY) datasets, satellite-based irradiance estimates, and ground-based measurements, offer unique insights into the solar potential.

As projects progress into site-specific planning, the integration of ground-based measurements refines assessments, offering granular insights into local conditions and potential shading effects. Furthermore, ground-based observations, play a vital role in operational monitoring, enabling real-time performance evaluation and maintenance scheduling.

In PV applications, the most relevant instruments include thermopile pyranometers, photodiode pyranometers, and photovoltaic reference cells, each offering a choice between precision, stability, and cost.

Importance of diffuse irradiance

All the instruments mentioned measure global irradiance, which usually consists of direct irradiance coming from the sun and a small addition of so-called diffuse irradiance which is commonly considered secondary if not irrelevant.

Diffuse radiation is the amount of light from the sky that reaches a surface after scattering on molecules and particles in the atmosphere. Diffuse irradiance is distinct from direct irradiance, which refers to the light that reaches a surface in a straight line from the sun without scattering. Together, these two components make up the total or global irradiance received by a surface which is traditionally being measured in PV parks. Direct irradiance carries most of the energy, and thus is key. Except for cloudy days and locations with predominantly cloudy climate.

With new PV technologies though a better response to dynamic weather conditions and cloudy skies has become more and more important, and a better understanding and estimate of the diffuse irradiance is needed to effectively use the power of a cloudy sky. The rapidly advancing bifacial PV modules capture light from both sides of the solar panel, and the PV systems can be better optimized to harness cloudy and overcast conditions, especially in environments with high ground reflectivity or snowfalls.

On cloudy or overcast days, the majority of irradiance is diffuse. In such conditions the

1 **MS-80SH Pyranometer***
ISO 9060 Class A Spectrally Flat & Fast response

2 **Rotating Shadow Band**
All-in-one DHI, GHI, and DNI data solution

3 **Control Unit C-Box**
With GPS & Modbus 485 Output

4 **OBI Software**
Compatible with **MS-80SH Plus+ & MS-90 Plus+**

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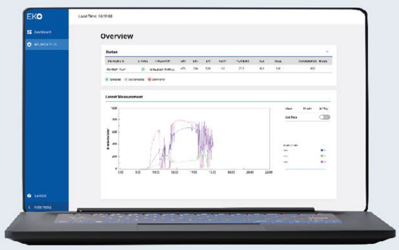
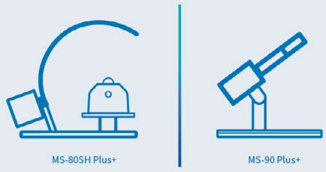




Powered by EKO

*With integrated high-efficiency dome heating

Features

- Cost-effective, no sun-tracker required
- Inbuilt GPS for quick, accurate setup
- DHI, GHI, and DNI measurements in one compact solution
- Fewer sensors = low maintenance requirements
- Easy integration with any DAQ system
- Low power consumption

diffuse irradiance that originates from the hemispheric sky with a relatively isotropic behaviour, together with ground-reflected irradiance, dominate the direct sunshine, making the bifacial modules surpass monofacial ones that rely mostly on direct irradiance. Counter-intuitively, when maximizing electricity production with a bifacial PV tracking system under overcast conditions, sun tracking may become ineffective, and it is instead advantageous to position the PV modules horizontally towards the zenith.

In fact, even under clear skies and specific atmospheric conditions such as high turbidity or low sun elevation angles, diffuse radiation can contribute up to 40% of the total global radiation received by a surface. This dispersed light, further scattered by clouds and airborne particles, forms diffuse irradiance, potentially reaching 100% on cloudy days.

Measuring diffuse irradiance

For ground-based solar radiation measurements, pyranometers serve as primary instruments for quantifying global, total, irradiance. However, their capabilities extend beyond the global irradiance measurement. Coupled with shading devices, they facilitate the determination of the diffuse component, thus enabling a comprehensive assessment of solar radiative fluxes.

The problem is, it is not that simple in practice. The most accurate method to gauge solar irradiance in situ, involves using a solar monitoring station equipped with an automated tracker, a pyrheliometer, and two pyranometers, one shaded and one unshaded.

By coupling the MS-80SH Pyranometer with the newly developed Rotating Shadow Band, RSB-02, we offer a comprehensive solution to monitor solar irradiance with particular focus on diffuse component.

The pyrheliometer constantly measures the Direct Normal Irradiance (DNI) by pointing directly at the sun, while the shaded pyranometer measures diffuse irradiance using a special ball or disc mounted on the same tracker to keep the pyranometer shaded at all times. By combining these measurements and knowing the sun's zenith angle, the global irradiance can be calculated.

Additionally, many solar monitoring stations include a separate pyranometer to independently measure the Global Horizontal Irradiance (GHI), providing redundancy in data collection. This redundancy allows for easy detection of errors in the data, such as sensor soiling or misalignment, by evaluating GHI radiation closure.

The most advanced solar radiation stations, such as the Baseline for Surface Radiation Network (BSRN), make use of tracker-based measurements to collect precise data on surface radiation fluxes, aiding climate research, renewable energy assessment, and atmospheric modelling. Sun-Tracker based measurements provides highly accurate measurements for research institutes but is far from being practical to be widely used at PV sites. It requires careful maintenance, and it may be simply too expensive and too complicated for general industrial applications.

Another possibility is the use of two pyranometers, a shaded and unshaded one, to measure global GHI and diffuse DHI components, enabling the calculation of the DNI. The shading can be provided by a shadow ring.

The primary benefit of the shadow ring lies in its simplicity of operation and its ability to directly estimate the diffuse component of solar radiation. However, it comes with the drawback of the consistent underestimation of diffuse solar radiation caused by the blocking effect of the ring, as well as the added need for maintenance to regularly adjust the ring to match the sun-path during the year.

There are other solutions available on the market that measure direct irradiance and then estimate diffuse component. The MS-90 tracker-less DNI sensor, combined with a pyranometer measuring GHI, enables reasonably accurate estimation of DHI with reduced maintenance efforts.

The main drawback of using such systems to measure the diffuse irradiance is that the diffuse component is not measured but calculated which increases uncertainty. Tracking devices offer more accurate estimations of diffuse solar radiation specially during clear sky conditions. Conversely, under completely cloudy conditions, the shading elements provide comparable results.

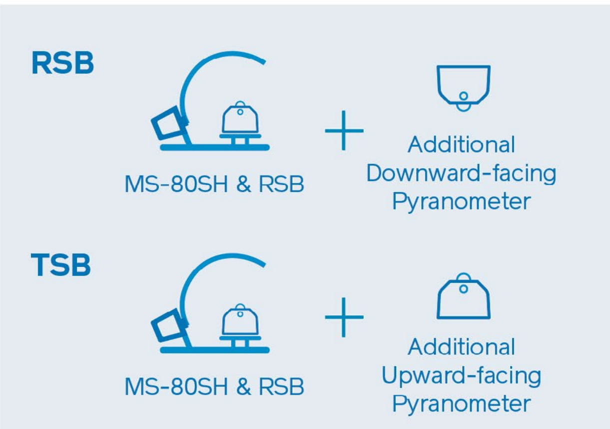
An alternative option involves employing an automated rotating shading band with a single detector. Traditionally, this measurement technique has predominantly utilized silicon photodiode pyranometers due to their rapid response time. Photodiode pyranometers, unlike their thermopile counterparts, utilize silicon-based sensors that mimic the spectral behavior of solar cells.

The use of photodiode pyranometers introduces measurement errors due to spectral effects, particularly during dynamic weather conditions transitioning from clear to cloudy skies. To attain accurate diffuse irradiance measurements with such devices, thorough characterization and corrections are necessary.

Introducing MS80SH Plus+

With EKO's MS-80SH Class A Fast Response and Spectrally Flat Pyranometer, there is a better way of using the RSB methodology. With the goal of achieving both cost-effective and accurate diffuse irradiance measurements we developed the MS80SH Plus+ solution.

By coupling the MS-80SH Pyranometer with the newly developed Rotating Shadow Band, RSB-02, we offer a comprehensive solution to monitor solar irradiance with particular focus on diffuse component. The system uses a stationary pyranometer, a motorized rotating band, and a smart Control and Processing Unit (C-Box). With an integrated GPS receiver, it accurately determines the time and location, calculates solar position and dynamically positions the RSB-02 shadow band to shade and open the pyranometer in a carefully controlled way.



	RSB mode	TSB mode
Pyranometer 1	GHI, DHI, DNI	DHI
Pyranometer 2	RHI, Albedo	GHI, DNI
Measurement Interval	15 sec	1 sec

STR-21 G-S2

Highest Accuracy | More Maintenance Required | Higher Cost

MS-80SH Plus+

High Accuracy | Least Maintenance Required | Lower Cost

MS-90 Plus+

Medium Accuracy | Less Maintenance Required | Lower Cost

RSR-01 Shading Ring

Medium Accuracy | Most Maintenance Required | Lower Cost

This way the MS80SH Plus+ system captures both global GHI and diffuse DHI components, and further calculates direct DNI component. Furthermore, our solution offers the flexibility to incorporate an additional pyranometer for measuring Reflected Horizontal Irradiance (RHI), allowing for precise determination of albedo. This additional feature enhances the system's adaptability, catering to a wide range of research and practical applications.

The total measurement cycle for the three components in the default RSB mode allows sampling irradiance with 15 seconds.

An additional operating mode, the Tracking Shadow Band (TSB) mode, offers full focus on Diffuse irradiance by ensuring a steady position of the band to intersect the sun's beam and keep a continuous DHI data output. When combined with a second, unshaded pyranometer, the dynamic tracking capability enables the same comprehensive measurements of GHI, DHI, and DNI with the highest sampling rate of one sample every second.

The system seamlessly integrates with digital data acquisition systems, dataloggers, SCADA systems, and other digital platforms through Modbus RTU interface over RS-485. And, with a focus on ensuring quality data for resource assessment and PV monitoring, this system incorporates specialized onboard functions. These include robust data quality checks based on BSRN criteria, as well as a transposition algorithm to directly yield Plane of Array irradiance estimates for each individual measurement.

To further compliment the measurements EKO offers Obi, a Windows software for data visualization and interactive access to the measurement data. Obi supports both MS80SH Plus+ and MS-90 Plus+ solutions and provides step-by-step instrument installation guidance, as well as additional capabilities for setting management and onboard diagnostics.

As we assess the intricate dynamics of solar irradiance, it becomes evident that understanding and harnessing the power of diffuse irradiance is paramount for unlocking the full potential of solar photovoltaic systems. With the release of the MS-80SH Plus+ monitoring solution, our aim is to equip engineers and scientists with the tools to enhance performance and foster sustainable advancements in the solar PV sector.

www.eko-instruments.com

Don't miss out on the opportunity to see our measurement solutions at Intersolar Europe München, held from June 19th to 21st, 2024. Visit us at Booth Number B4.1 for an exclusive preview.