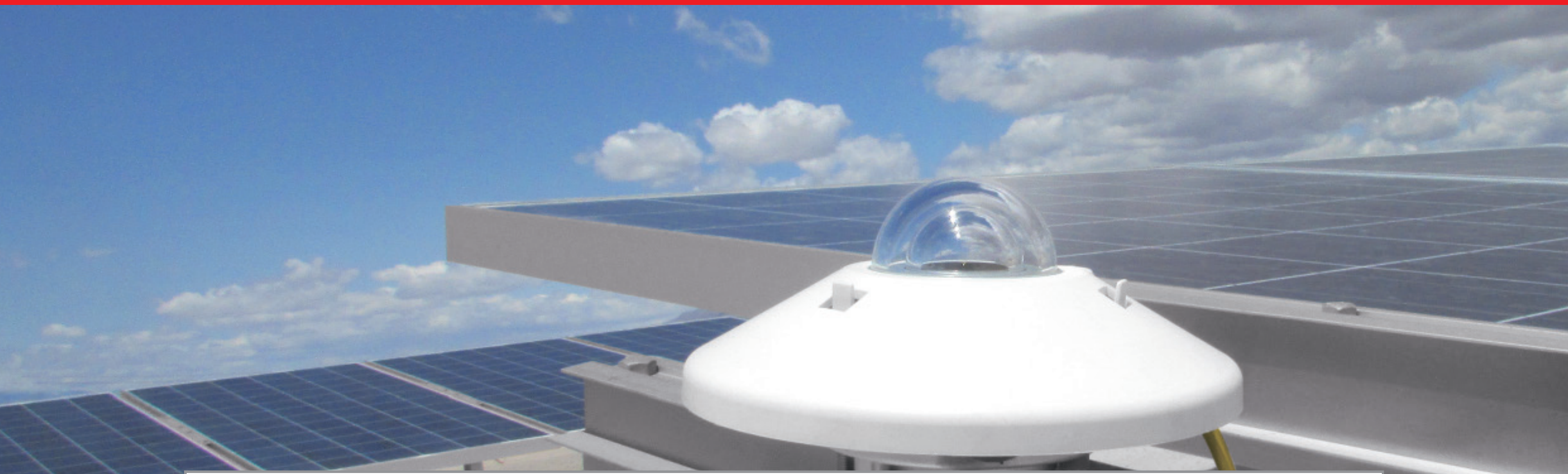


optimal solutions and systems

Solar Irradiance Monitoring in Solar Energy Projects

Learn what is important in solar irradiance measurements in solar energy projects. Find optimal solutions and systems for PV, CPV and CSP projects.

Solar radiation is the input for all solar energy generation systems. Measuring solar irradiance provides knowledge to make important decisions on future energy yield, efficiency, performance and maintenance – crucial factors for investments!

This brochure provides helpful guidelines for Photovoltaic and Solar Thermal projects, including practical information on site prospecting and the efficiency monitoring of solar power plants.

Glossary of Terms

Irradiance	radiant flux received by a surface per unit area, irradiance is measured in W/m^2
Direct Normal Irradiance (DNI)	DNI is the amount of solar radiation received per unit area by a surface that is held perpendicular (normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky. DNI is measured by a pyrheliometer with a field of view of 5°, mounted on an automatic sun tracker.
Diffuse Horizontal Irradiance (DHI)	DHI characterizes the amount of energy coming from the sky after being scattered in the atmosphere. DHI is measured by a pyranometer shaded from the direct sunlight.
Global Horizontal Irradiance (GHI)	GHI is the amount of solar radiation received per unit area by a horizontal surface from the hemisphere above. It comprises Direct Normal Irradiance, corrected for the angle of incidence on the surface, and Diffuse Horizontal Irradiance. The relationship is; $GHI = DHI + DNI \cdot \cos(\theta)$, where θ is the solar zenith angle (vertically above the location is 0°, horizontal is 90°). GHI is measured by a pyranometer mounted horizontally.
Plane of Array (POA) irradiance	Also known as Global Tilted Irradiance (GTI) - irradiance incident on the tilted plane (i.e. PV panel). POA irradiance is difficult to calculate from other measurements due to the complex nature of radiation reflected from the ground and shadowing effects. It can be accurately measured by a pyranometer installed at the same tilt angle as the PV panels.

What we can do for you

Kipp & Zonen provides a wide range of products to measure solar radiation accurately and reliably:

- Proven quality: ISO 9001:2008 certified company.
- More than 85 years of experience and expertise in solar radiation measurement equipment
- Worldwide reference customer base
- Worldwide network of representatives: 4 sales offices and 45 distributors around the globe
- Technical services, installation, calibrations and training available worldwide
- Useful accessories for easy installation and maintenance
- Advice on applications and best practices

Site Prospecting and Energy Forecast

Where to build a solar power plant? Which technology will have the lowest levelized cost of energy (LCOE) and bring maximum return on investment (ROI)? What is the optimal size of the power plant on a given site? Knowing the amount and distribution of solar irradiance with low uncertainties will help to answer such questions.

The amount of solar radiation available over time under the local environmental conditions is a key input for choosing the optimal location, technology and size of a solar energy project. Feasibility studies and technical due diligence calculations of a solar energy project always start with energy resource assessment.

High precision on-site measurements of solar radiation provide the lowest uncertainty for bankable data about the energy resource and the possible energy yield. Such measurements are performed by a high quality solar radiation monitoring station that measures all three components of solar radiation: direct normal irradiance (DNI), diffuse horizontal irradiance (DHI) and global horizontal irradiance (GHI). Also, other meteorological parameters relevant to the project, such as air temperature, humidity, precipitation, wind speed and direction need to be monitored by a dedicated weather station.

A complete solar monitoring station consists of a pyrheliometer mounted on an automatic sun tracker for measurements of DNI, a shaded pyranometer for measurements of DHI and an unshaded pyranometer for measuring GHI; plus a high performance data logger to acquire and store the measured values.

Solar monitoring stations can be extended by spectral instruments and/or a sky radiometer to study the aerosol concentrations in the atmosphere, which is especially important in arid desert areas with high concentrations of sand and dust, in the air.

Recommended system

SOLYS2 automatic sun tracker, with shading ball assembly and sun sensor (for active tracking), fitted with:

ISO 9060 First Class pyrheliometer
for DNI measurement (CHP1 or SHP1)

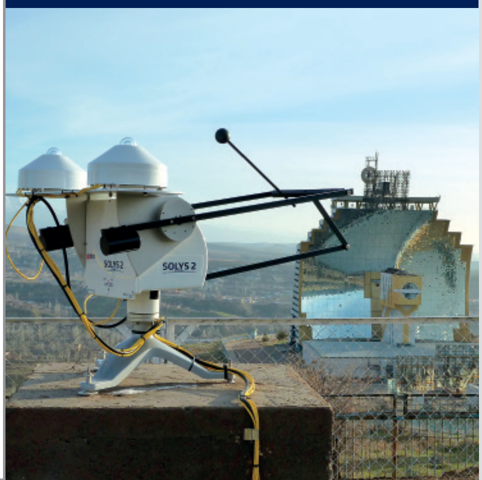
Two ISO 9060 Secondary Standard pyranometers, of which one unshaded for GHI measurement and one shaded for DHI measurement (CMP10 or SMP10)

Ventilation units for pyranometers, depending upon the site environment (CVF4)

Weather station with air temperature, humidity, precipitation, wind speed and direction sensors

High quality meteorological data logger

Optional POM-01 or POM-02 sky radiometer



Automatic sun tracker SOLYS2 with a pyrheliometer and two ventilated pyranometers. The ventilation units help to keep the pyranometer domes clean from dust and dew.

Fixed Photovoltaic (PV) Installations

Recommended system

SMP3 or SMP10 pyranometer for POA measurements, LOGBOX datalogger

An additional pyranometer for GHI is optional

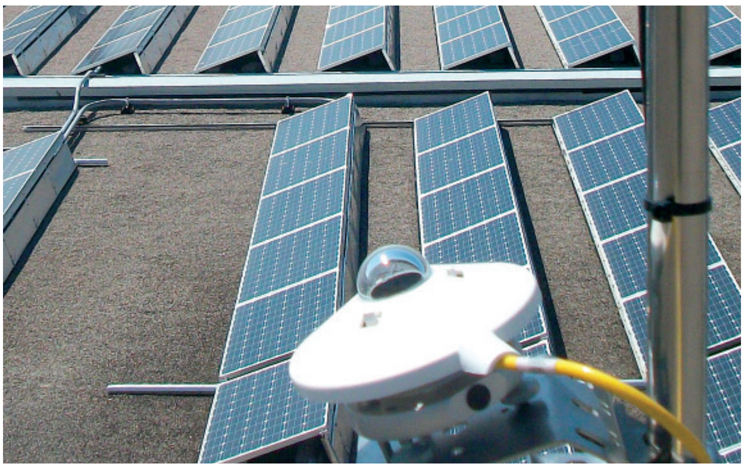
Rooftop installations, Building Integrated Photovoltaic (BIPV) systems and small ground-mounted PV plants (kW range)

For both roof and ground-mounted installations solar radiation measurements significantly improves the monitoring of the performance of the solar energy system.

In most smaller PV installations, if any monitoring is done, it is usually a comparison of the output from one PV panel to another PV panel. You then monitor the relative efficiency and can detect a faulty panel or connection. Although useful, it actually doesn't tell you whether you get the maximum out of your system. As long as you do not measure the input of solar radiance into to the PV installation, you will not know whether you should be satisfied with the output of your PV installation.

To monitor the energy yield of the PV installation a tilted pyranometer is installed at the same angle as the panels to measure plane of array (POA) irradiance. A horizontal pyranometer can be added for global horizontal irradiance (GHI) measurements – this allows comparison of the on-site data to other sites and to data received from meteorological stations.

Cost-efficient low-maintenance smart pyranometers SMP3 (ISO 9060 Second Class) and SMP10 (ISO 9060 Secondary Standard) are ideal for small scale installations. Smart pyranometers have internal digital signal processing, an amplified analogue output (4 to 20 mA or 0 to 1 V) and a RS-485 serial communication with Modbus® protocol. They can be directly connected to modern inverters and easily integrated into digital supervisory control and data acquisition (SCADA) systems.



Medium and large commercial PV installations (MW range)

In medium and large installations (>1 MW) the uncertainties in the efficiency of energy generation have considerable impact on the project´s profitability. A measurement uncertainty of as low as a couple of percent for a plant of nominal capacity of several MW can mean a significant difference in energy production forecasts and can therefore directly impact profit or loss!

Measurements of POA and GHI irradiance are crucial for determining performance ratios and monitoring energy yield efficiency. Performance ratio monitoring requires high quality measurement instruments and reliable data collection. It is recommended to use ISO 9060 Secondary Standard pyranometers for the highest quality of the data, for example the CMP10 or SMP10 low maintenance pyranometers.

For large scale plants a high quality solar monitoring station is recommended for measurement of all three components of solar radiation (GHI, DHI and DNI). This data can be complimented by monitoring POA irradiance at several sites on the plant, typically feeding into the array inverters.

Smart pyranometers with RS-485 Modbus® are addressable, can be linked to a single network loop and can be integrated into the SCADA system of a solar plant for easy and practical monitoring and reduced cable costs.

Large projects often span an area where meteorological conditions might vary due to differences in microclimate. In these cases solar monitoring stations and weather stations may need to be placed in several parts of the plant to closely monitor the local conditions.

Using two or more solar monitoring points ensures redundancy of the measurements. When some of the instruments need to be replaced or sent for calibration, the data collection will remain continuous.

Recommended basic system

A minimum of two ISO 9060 Secondary Standard pyranometers, one for POA and one for GHI measurement (CMP10 or SMP10)

For larger plants, additional pyranometers should be installed, distributed over the site

Recommended advanced system

SOLYS2 automatic sun tracker, with shading ball assembly and sun sensor (for active tracking), fitted with:

ISO 9060 First Class pyrheliometer
for DNI measurement (CHP1 or SHP1)

Two ISO 9060 Secondary Standard pyranometers, of which one unshaded for GHI measurement and one shaded for DHI measurement (CMP10 or SMP10)

Ventilation units for pyranometers, depending upon the site environment (CVF4)

Weather station with air temperature, humidity, precipitation, wind speed and direction sensors

High quality meteorological data logger

Tracking Photovoltaic (PV) Systems

PV systems with one- or two-axis tracking can considerably increase the output of solar panels by ensuring higher received irradiance during the day. To monitor the performance of the system the POA irradiance should be measured, along with the GHI, using high quality pyranometers (ISO 9060 Secondary Standard). The pyranometers can be mounted on the solar panel tracker or on a dedicated high precision sun tracker.

Recommended system

Two ISO 9060 Secondary Standard pyranometers (CMP10 or SMP10), one for GHI measurement and one mounted on panel tracker for POA measurement

For larger plants, additional pyranometers should be installed, distributed over the site

Concentrating Photovoltaic (CPV) Systems

CPV systems use optics to concentrate a large area of sunlight onto a small solar cell and are either refractive (with lenses) or reflective (with mirrors). To achieve high concentration ratios the optics have a narrow field of view and only make use of direct normal irradiance (DNI) from the sun.

DNI is most accurately measured by a high quality pyrheliometer mounted on a precise automatic sun tracker to provide reliable data about the solar radiation input. An advanced system with pyranometers measuring diffuse and global irradiance (DHI and GHI) can provide a quality check of the DNI measurements.

Recommended basic system

SOLYS2 automatic sun tracker with sun sensor for active tracking and small top plate, fitted with:

ISO 9060 First Class pyrheliometer for DNI measurement (CHP1 or SHP1)

ISO 9060 Secondary Standard pyranometer for GHI measurement (CMP10, SMP10, CMP21 or CMP22)

Ventilation unit for pyranometer, depending upon the site environment (CVF4)

High quality meteorological data logger

Recommended advanced system

As the basic system, plus:

Shading assembly

Second pyranometer for DHI measurement (CMP10, SMP10, CMP21 or CMP22)

Weather station with air temperature, humidity, precipitation, wind speed and direction sensors

Concentrating Solar Power (CSP) Systems

Thermal systems use the direct normal irradiance (DNI) from the sun to generate heat, which can be used as the energy source for steam turbine electricity generators. These systems use mirrors to concentrate solar radiation. Unlike PV cells, they can take advantage of the full spectrum of solar radiation, including ultraviolet and near infrared light, leading to high efficiencies. For such systems it is extremely important to monitor the broadband solar radiation with high precision, because sky conditions have a strong influence on the performance of a CSP plant.

To predict the energy yield of a CSP system with a minimum of uncertainty it is crucial to measure solar radiation locally. Satellite measurements and related models don't take into account the effect of local climatic conditions, such as clouds, nor do they include the effect of local aerosols (dust, sand and other particles). Two CSP plants in different locations with equal direct irradiance totals, according to satellite data, may have very different energy outputs, due to differences in clouds and aerosols in the particular locations, which affect the incoming radiation.

To ensure the reliability and redundancy of the data, a typical CSP solar monitoring station uses high precision instruments with low uncertainty for the measurements of direct, diffuse and global irradiance. This way the direct radiation measurement can be compared with values derived from the global and diffuse radiation. This allows detection of problems with a particular instrument, for example due to soiling.

The overall effect of aerosols on the incoming radiation can simply be measured by solar irradiance sensors, but to study the type of aerosols to improve predictions of solar energy available over time, one should use a sky radiometer, such as the POM-01 or POM-02.

Recommended system

SOLYS2 automatic sun tracker, with shading ball assembly and sun sensor (for active tracking), fitted with:

ISO 9060 First Class pyrheliometer, for DNI measurement (CHP1 or SHP1)

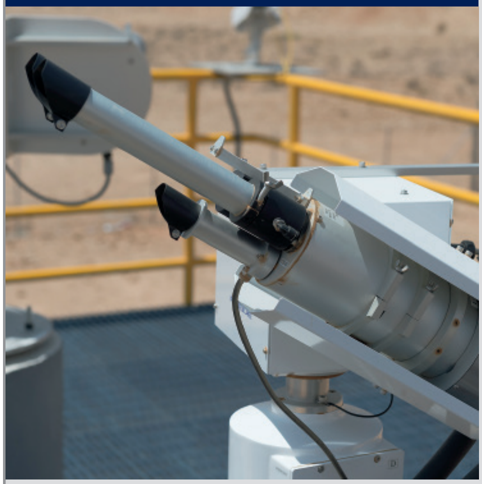
Two ISO 9060 Secondary Standard pyranometers, of which one unshaded for GHI measurement and one shaded for DHI measurement (CMP10, SMP10, CMP21 or CMP22)

Ventilation units for pyranometers, depending upon the site environment (CVF4)

Weather station with air temperature, humidity, precipitation, wind speed and direction sensors

High quality meteorological data logger

Optional POM-01 or POM-02 sky radiometer



Choosing the Right System

Application	Measurement Parameters		Measurements Instruments
	Basic	Advanced	
Prospecting	DNI, GHI, DHI, weather, data logger		Automatic sun tracker: SOLYS2 ISO 9060 First Class pyrheliometer: CHP1 or SHP1 ISO 9060 Secondary Standard pyranometers: CMP10 or SMP10 Weather station
Fixed PV Small	POA, GHI optional		Smart pyranometers SMP3 or SMP10 integrated into monitoring system
Fixed PV Medium	POA, GHI	POA, GHI, at least 2 locations, weather, data logger	ISO 9060 Secondary Standard pyranometers: CMP10 or SMP10 Weather station
Fixed PV Large	GHI, at least 2 locations, distributed POA	POA, GHI, DNI, DHI, distributed POA, weather, data logger	Automatic sun tracker: SOLYS2 ISO 9060 First Class pyrheliometer: CHP1 or SHP1 ISO 9060 Secondary Standard pyranometers: CMP10 or SMP10 Weather station
Tracking PV	POA, GHI	DNI, GHI, DHI, weather, data logger	ISO 9060 First Class pyrheliometer: CHP1 or SHP1
CPV	DNI, GHI, data logger	DNI, GHI, DHI, weather, data logger	Automatic sun tracker: SOLYS2 ISO 9060 First Class pyrheliometer: CHP1 or SHP1 ISO 9060 Secondary Standard pyranometers: CMP10 or SMP10 Weather station
CSP	DNI, GHI, DHI, weather, data logger		Automatic sun tracker: SOLYS2 ISO 9060 First Class pyrheliometer: CHP1 or SHP1 ISO 9060 Secondary Standard pyranometers: CMP10, SMP10, CMP21 or CMP22 Weather station

Kipp & Zonen and its local representatives can also design and offer complete solutions for solar monitoring at solar energy projects including:

- Dataloggers for data acquisition
- Communication systems for data transmission
- PV module temperature sensors
- Weather stations

Please contact us to discuss your solar energy project.

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