On-Site Solar Measurements for Bifacial Projects

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Abstract

On-site solar resource measurements are often considered valuable for the development of utility-scale solar projects. As utility-scale bifacial PV projects have become more prominent, project stakeholders are developing new solar measurement approaches to facilitate bifacial energy modeling and reduce bifacial energy uncertainty.

Objectives

This poster outlines recommended solar measurement practices, especially as they relate to future bifacial projects seeking external financing. The poster demonstrates the technical and financial value of on-site measurements in the following categories.

- Class A redundant global horizontal irradiance (GHI)
- Diffuse horizontal irradiance (DHI)
- Albedo for bifacial applications
- Additional meteorological measurements for energy modeling

Solar Measurement Standards

UL generally recommends that measurements systems be designed and advised by applicable and relevant standards and industry-wide guidance documents, such as the following:

- ISO 9060:2018(E): *Solar Energy – Specification and Classification of Instruments for Measuring Hemispherical Solar and Direct Solar Radiation*
- IEC 61724-1:2017: *Photovoltaic System Performance – Part 1: Solar Monitoring*
- WMO 8th Ed.:2010: *Guide to Meteorological Instruments and Methods of Observation*
- ASTM G213-17: *Standard Guide for Evaluating Uncertainty in Calibration and Field Measurements of Broadband Irradiance with Pyranometers and Pyrheliometers*

UL notes that some of the industry standards were developed for broad applications. Others were developed with an intended focus that differs from pre-construction remote measurements. Therefore, UL's approach is to use these standards for guidance rather than rigidly applying them to the unique and specific application of pre-construction measurement collection.

Class A Redundant GHI Measurements

For pre-construction applications, UL recommends that the selected solar meteorological equipment, monitoring plan, and maintenance approach is in general agreement with the practices expected for Class A equipment and measurements according to ISO 9060-2018 and IEC 61724-1:2017.

While a variety of pyranometer types and configurations may be suitable depending on the application (region, project classification/size, vintage of measurements), UL recommends the following specifics for pyranometers and supporting equipment.

Class A Pyranometers. Pyranometers are rated by their performance for a variety of metrics: response time, non-stability (drift), non-linearity, spectral selectivity, temperature dependence, and tilt response, and their achievable accuracy. Class A pyranometers are tested to applicable standards to verify their compliance to these performance categories, and are able to achieve high measurement accuracy.

Redundant Pyranometers. UL recommends at least two Class A pyranometers, preferably procured from different pyranometer suppliers to mitigate single-supplier risks and to allow for a diversity of high-class measurement equipment.

Heating and Ventilation. Pyranometers are often paired with heating and ventilation units, or may employ internal heating and ventilation. Each ventilation strategy—external and internal—has advantages and challenges, as shown in the table below.

Strategy	External Ventilation	Internal Ventilation
Ventilation Mechanism	*Convective airflow over external dome of pyranometer*	*Warm convective airflow between two glass domes of pyranometer*
Advantages	•Consistent with purpose of ventilation in industry documents •Minimizes accumulation of debris on outer dome	•Less power consumption, resulting in lower system cost •Smaller cover limits snow collection on device radiation shield
Challenges	•Higher power consumption, increasing system cost •Increased likelihood of snow collection on large ventilation cover	•Debris accumulation on outer dome not mitigated by ventilation, requiring manual cleaning

Maintenance. Weekly on-site maintenance of pyranometers (and albedometers) is required to maximize measurement accuracy. When neglected for long periods, measurement accuracy can degrade by as much as 5-10% due to a change in the orientation of the sensor or due to the accumulation of debris, snow, or bird droppings.

Lack of maintenance effectively defeats the purpose of the on-site measurement campaign because high-quality satellite-modeled data can achieve uncertainties that are comparable to the uncertainty of an un-maintained pyranometer.

Albedo Measurements for Bifacial Systems

For traditional monofacial PV systems, albedo is a small contributor to energy production at most sites. However, albedo is a direct contributor to back-side irradiance and bifacial energy production. For a typical tracking bifacial system, a 3% increase in annual albedo (e.g., 23% vs. 20%) can result in up to a 10% increase in back-side energy, corresponding to about a 1% increase in the bifacial system's overall energy. For bifacial projects, the following field considerations are recommended.

Ground Conditions. The ground conditions in the albedometer's field of vision should be prepared and maintained on a regular basis to closely match the future PV system's anticipated ground conditions. This may require vegetation or water management during the pre-construction measurement period.

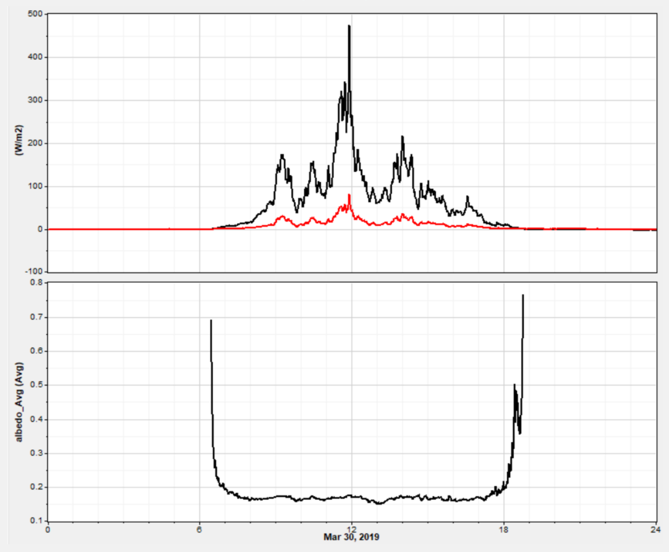
Albedometer Mounting. As much as possible, the albedometer's downward-facing component should have an unobstructed field of vision. A proper mounting configuration mitigates the likelihood of sun reflection from nearby structures or from the albedometer's mounting hardware, which should be prepared accordingly.

Height Above Ground. As with pyranometers, albedometers must be mounted to avoid shading impact on the upward facing instrument. This becomes a greater challenge when considering the lower height of most albedometers, and can be mitigated by placing albedometers on the sunward (usually southern) side of other measurement equipment.

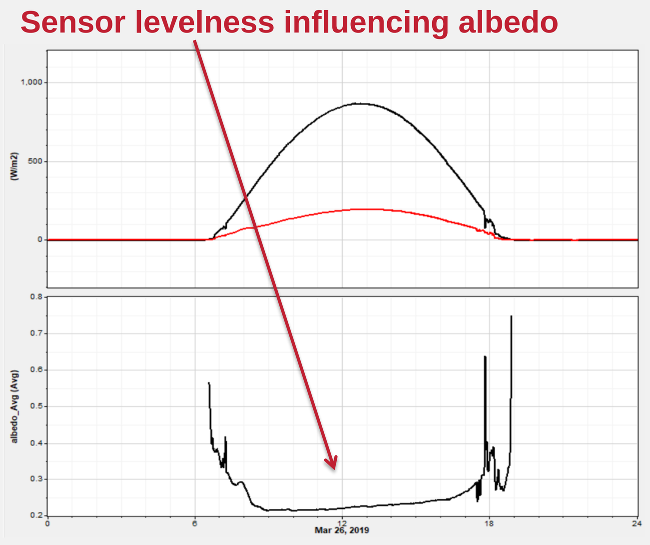
Azimuthal Orientation. To prevent mounting hardware shadows from falling within the albedometer's downward field of vision, the albedometer is often oriented at an azimuth of 180 degrees and on the sunward side of other measurement equipment.

Shadow Mitigation. Structures to the south, east, and west of the albedometer (including other measurement equipment and fencing) should be sufficiently far away to prevent them from casting shadows over both the upward-facing albedometer component and the downward field of vision.

Albedo on cloudy day

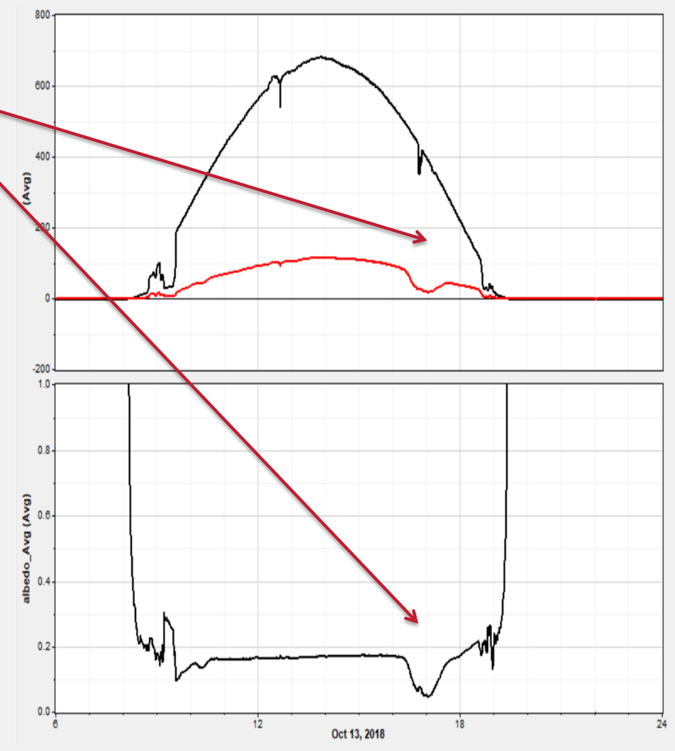


Sensor levelness influencing albedo

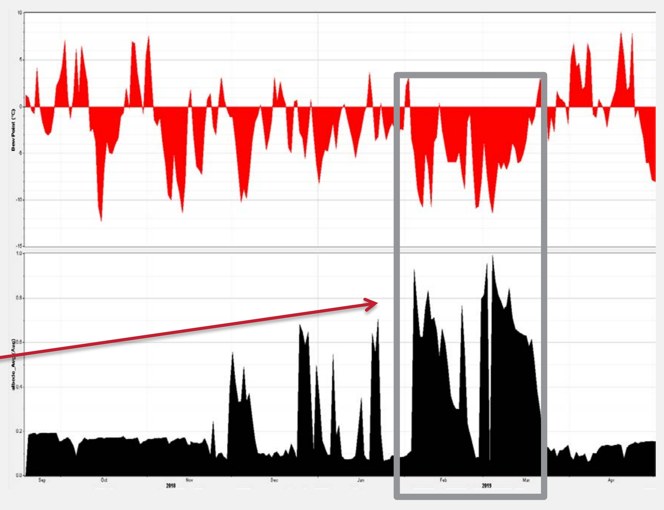


Standing water in downward field of vision

Afternoon tree shading in albedometer field of vision due to space constraints (to accommodate operational PV array)



Influence of repeated fresh snow events on albedo measurements. Consider: (1) upward pyranometer condition, and (2) direct correlation with PV snow loss due to accumulation on PV arrays.



Diffuse Horizontal Measurements

Since diffuse horizontal irradiance (DHI) is an input to the calculation of plane-of-array irradiance (POA) for PV energy modeling, DHI accuracy has some impact on the overall energy estimate's accuracy. Due to the transposition model, energy production varies inversely with DHI. For example, a decrease in DHI of 5% might lead to a 1-2% increase in energy. For bifacial systems, DHI is also a secondary but direct contributor to back-side irradiance and energy generation: for example, a 5% increase in DHI can lead to about a 2% (normalized) increase in back-side energy.

The most accurate DHI measurements involve telescoping trackers that block out the direct component of sunlight. In practice these trackers can easily be misaligned by environmental conditions and require nearly constant attention to maintain. For remote systems, a more reliable and reasonably accurate approach for diffuse measurements is to rely on fixed shaded instrumentation that require less frequent maintenance. While these devices may have uncertainty in the 4-6% range, measurements from these devices are expected to be more accurate than the alternative DHI data estimated from high-quality satellite models.

Supporting Meteorological Measurements

Supporting meteorological data is often collected concurrently to help validate irradiance data and support energy simulation and loss assumptions.

- **Precipitation data** are helpful to confirm rain events associated with cloud cover and for correlations to estimate the PV array soiling loss.
- **Wind speed** and **ambient temperature data** can be used to estimate thermal losses of PV arrays during the energy simulation process.

Together, the ensemble of measurements characterizes site conditions and allow for intelligent judgement to be applied when validating irradiance data.

Measurement Type	Purpose	Measurement Accuracy	Percent Impact on Energy
GHI	Principle measurement for solar resource assessment	1-2%	A 2% increase in GHI corresponds to about 1.5% increase in energy
POA	Assists with verifying POA transposition model accuracy	1-2%	A 2% increase in POA corresponds to a similar increase in energy
DHI	Increases accuracy of POA transposition for energy modeling	4-6%	A 5% decrease in DHI corresponds to a 1-2% increase in energy (because of DNI relationship)
Albedo	Improves characterization of back-side POA for bifacial projects	2-4%	For tracking system, 3% increase corresponds to about 10% increase in back-side irradiance, about 1% increase in overall energy
Temperature	Improves accuracy of non-STC temperature loss for PV projects	0.5°C	A 3°C increase in temperature corresponds to a loss increase of about 1%
Wind Speed	Improves accuracy of non-STC temperature loss for PV projects	0.5 m/s	(Dependent on site conditions)
Relative Humidity	Improves accuracy of spectral performance modeling	3%	(Dependent on PV technology)
Precipitation	Frequency of rain/snow events for module cleaning	1%	Informs soiling and snow loss
Soiling System	Power loss due to dirt, debris, snow	(Dependent on system design)	Informs soiling and snow loss

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