Introducing the Baseline Performance Reference (BPR) for Irradiance in PV System Applications

Anton Driesse,[1] Aron Habte,[2] and Manajit Sengupta[2]

[1]PV Performance Labs, Freiburg, Germany,

[2]National Renewable Energy Laboratory, Golden, CO, United States

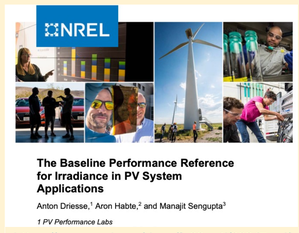
Introduction

Photovoltaic (PV) reference cells, modules, and arrays respond in a complex manner to the many variables that define their operating environment. PV reference cells for irradiance measurement have similarities but also differences to operational PV modules. For this reason, a more neutral and a well-defined generic PV reference cell is needed, whose characteristics are close enough to most operational PV devices to make stable performance indicators possible but whose characteristics are not necessarily identical to any of them. This poster describes a new well-defined reference quantity for outdoor PV measurements, which we call the baseline performance reference (BPR).

Pyranometers are well-defined reference devices for irradiance measurement and can be considered neutral because their characteristics are defined in a standard unrelated to PV technology; however, the relationship between broadband hemispherical irradiance measured by pyranometers and the magnitude of light-generated current in PV devices is complex. For this reason, performance indicators based on pyranometers strongly fluctuate. This would be avoided using the proposed BPR.

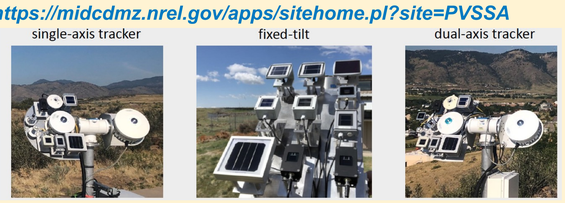
BPR Development Plan

Consultation through stakeholder engagement, publication, and data dissemination



https://www.nrel.gov/docs/fy23osti/86847.pdf

Data collected at NREL Solar Radiation Research Lab
https://midcdmz.nrel.gov/apps/sitehome.pl?site=PVSSA



Photos by NREL

Demonstration

Use cases such as:
- ❖ *Yield prediction*
- ❖ *Capacity testing and performance evaluation.*

Adaptation

Use cases such as output from the solar resource, e.g., the National Solar Radiation Database, and input to PV yield simulation software programs

Standardization

Similar to ISO 9060:2018 Solar energy: Specification and classification of instruments for measuring hemispherical solar and direct solar radiation

Product development

Modify or develop new reference cells that more closely conform to the BPR

Product testing

Product specification test to ensure that products qualify as BPR radiometers

Data Analysis Using Existing PV Reference Cells

$\frac{(max-min)}{mean}$ =4.1%

	ISET	ISET-P	RC01	RC18	Si2	SOZ-03	SOZ-03-P	WPVS
ISET	+0.00	+0.32	+0.79	−3.26	−0.85	−1.25	−0.26	−0.68
ISET-P	−0.32	+0.00	+0.48	−3.58	−1.17	−1.56	−0.58	−0.99
RC01	−0.79	−0.48	+0.00	−4.06	−1.65	−2.04	−1.05	−1.47
RC18	+3.26	+3.58	+4.06	+0.00	+2.41	+2.02	+3.00	+2.59
Si2	+0.85	+1.17	+1.65	−2.41	+0.00	−0.39	+0.59	+0.18
SOZ-03	+1.25	+1.56	+2.04	−2.02	+0.39	+0.00	+0.99	+0.57
SOZ-03-P	+0.26	+0.58	+1.05	−3.00	−0.59	−0.99	+0.00	−0.42
WPVS	+0.68	+0.99	+1.47	−2.59	−0.18	−0.57	+0.42	+0.00
mean	+0.65	+0.96	+1.44	−2.61	−0.20	−0.60	+0.39	−0.03

$\frac{(max-min)}{mean}$ =2%

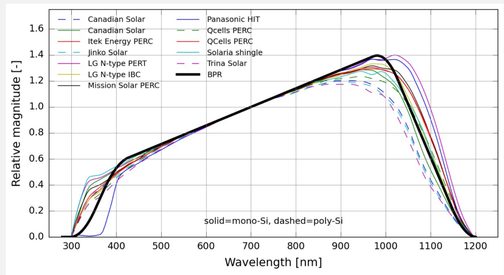
	ISET	ISET-P	RC01	RC18	Si2	SOZ-03	SOZ-03-P	WPVS
ISET	+0.00	−0.04	−0.08	−2.01	−0.39	−0.24	+0.06	−0.95
ISET-P	+0.04	+0.00	−0.04	−1.97	−0.35	−0.19	+0.10	−0.90
RC01	+0.08	+0.04	+0.00	−1.93	−0.31	−0.15	+0.14	−0.86
RC18	+2.01	+1.97	+1.93	+0.00	+1.62	+1.77	+2.07	+1.07
Si2	+0.39	+0.35	+0.31	−1.62	+0.00	+0.15	+0.45	−0.55
SOZ-03	+0.24	+0.19	+0.15	−1.77	−0.15	+0.00	+0.30	−0.71
SOZ-03-P	−0.06	−0.10	−0.14	−2.07	−0.45	−0.30	+0.00	−1.00
WPVS	+0.95	+0.90	+0.86	−1.07	+0.55	+0.71	+1.00	+0.00
mean	+0.46	+0.41	+0.37	−1.55	+0.07	+0.22	+0.51	−0.49

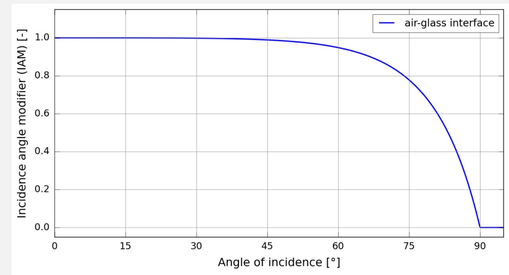
Comparison of annual POA energy at fixed tilt using factory calibration (left) and local field calibration (right)

Proposed BPR Specifications

Key BPR characteristics compared to existing PV reference cell standards

	ISO 9060	IEC 60904-2	ASTM E1040	WPVS	BPR
Directional response	Lambertian	Incompletely specified by physical package constraints			Air-glass interface
Temperature response	Flat	Linear correction	Linear correction	Operation at 25° C	Flat
Spectral response	Flat	Matched to the device under test			Simple idealization





BPR spectral response (left) and directional response (right)*

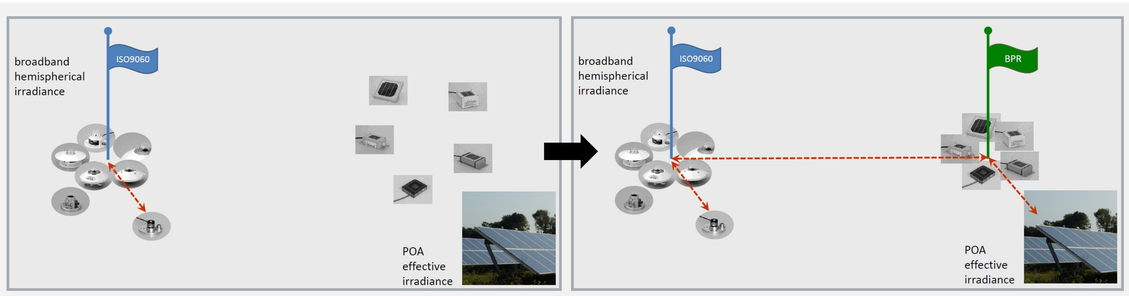
Summary

- BPR devices are not matched reference devices—that is, their characteristics are not chosen to match specific PV modules. Rather, their characteristics match a generic, partly idealized PV module behavior.
- First steps on the path to standardization have been taken, but much remains to be done to achieve acceptance and widespread adoption. Therefore, we seek to engage stakeholders, solicit feedback, encourage debate, and fine-tune the BPR concept as needed.

Looking Ahead

- The BPR definition opens the door to new practices in resource assessment and yield prediction.
- PV system simulations based on BPR irradiance need fewer assumptions and less processing to obtain the effective irradiance on modules, leading to reduce uncertainty in yield predictions.

A Visual Explanation of the BPR



The essence of the BPR idea using relative distances to indicate magnitudes of differences. The blue flag (left) currently guides pyranometer specifications creating a tight cluster.
The green flag (right) will guide future reference cell products leading to more consistent characteristics and traceable measurements.

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

** Module spectral responses providing context for the BPR have been published in:*
Driesse, Anton, Marios Theristis, and Joshua Stein. 2023. "Global Horizontal Spectral Irradiance and Module Spectral Response Measurements: An Open Dataset for PV Research." SAND2023-02045. Albuquerque: Sandia National Labs.

PV Performance Modeling and Monitoring Workshop
Salt Lake City, UT
May 7–9, 2024