Radiometric Standards and Best Practices: Recent Progress

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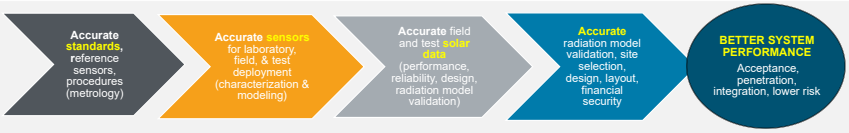
Abstract

- International standards and best practices for solar resource assessment provide assurance for traceable measurements associated with a low uncertainty.
- NREL, in collaboration with international organizations, such as subcommittees G03 of ASTM (radiometry) and TC 180/SC 1 of ISO (climate measurement and data), recently revised some standards that are widely used by the solar industry.
- These include radiometric standards that assist in (1) maintaining calibration traceability, (2) uncertainty analysis, (3) measurement quality assurance, and (4) establishing reference spectral irradiance distributions. The latter are widely used by the solar community to evaluate the actual absorptance, reflectance, and transmittance of solar energy materials, or the performance of solar energy devices and systems, relative to standard conditions.
- This poster provides a summary of the recent changes brought to these standards as a way to better support the solar energy industry.

Use Cases of Radiometric Standards for Solar Energy



Resource Characterization	Reliability and Durability	Measurement & Characterization	Industry Needs
• **Irradiance sensor deployment** • **Irradiance data for model validation** • **Data dissemination**	• Lab & outdoor irradiance measurement • Test chamber & outdoor UV measurement	• Spectral & broadband irradiance for reference PV device calibration • Solar simulator characterization	• Solar simulator classification • Spectral & broadband calibration • Irradiance data and models

Highlights of International Standards

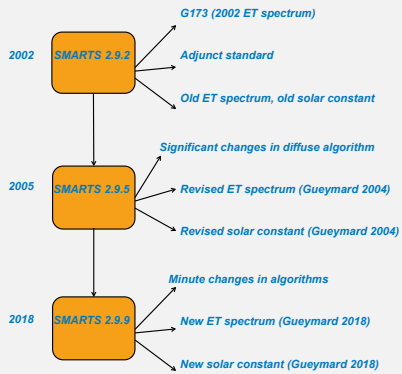
Standard Reference for Solar Spectral Energy Distributions

ASTM G03.09 Radiometry Subcommittee

- **G173-03(2020) Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37° Tilted Surface**

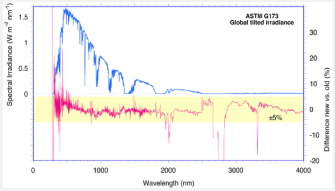
The new version of the SMARTS model, V2.9.9, contains:

- New solar constant: Based on a 42-year time series of recalibrated irradiance data, a revised solar constant of 1361.1 W•m−2 was recently accepted. This contrasts with the older World Meteorological Organization (WMO) value of 1367 W•m−2 that was used for the original version of G173.
- New revised extraterrestrial (ET) spectrum: It is based on a recalibration and merging of various sources of spaceborne ET observations and is included in the new SMARTS model version (V2.9.9). This new ET spectral distribution differs from the earlier ET spectrum used for the original version of G173 by small amount. This affects the UV and visible spectral bands, in particular.
- Various improvements in the spectral calculations of atmospheric effects, particularly affecting the UV.

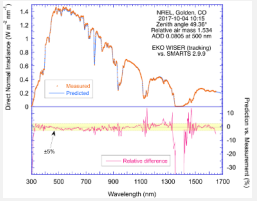


Validation of the New G173 Using SMARTS 2.9.9

Most changes are in the UV, where both the ET spectrum and the transmittance algorithm have undergone substantial changes.



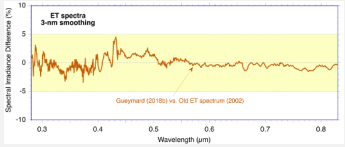
SMARTS 2.9.9 (new) versus SMARTS (old) 2.9.2



ASTM G173 vs. measured spectral data

There are better chances that the new spectra can be validated/verified using high-end spectral measurements at laboratories around the world. In other words, the new ET spectrum and SMARTS version have eliminated some sources of discrepancy and systematic errors [1].

• The new spectra would be directly harmonized with the new ASTM **E490-22 Standard Solar Constant and Zero Air Mass Solar Spectral Irradiance Tables.**



ASTM E490 (2022) is now based on:

- Revised solar constant [2] (from 1367 down to 1361.1 W/m^2; –0.4% systematic difference)
- Revised spectral distribution [3]; significant differences in UV and a few bands VIS-NIR

Broadband irradiances are only marginally affected.

Irradiance	Old	New	% diff. (new/old)
Solar constant	1367.0	1361.1	–0.43
G173 DNI	900.14	896.99	–0.35
G173 GTI	1000.37	1001.92	+0.15

Other International standards that use the SMARTS model will need to assess migration to the new SMARTS version, such as:

- ISO 9845-1:1992 Solar energy – Reference solar spectral irradiance at the ground at different receiving conditions – Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5
- IEC 60904-3:2016 Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data
- CIE 241:2020 Recommended reference solar spectra for industrial applications.

References

[1] Gueymard, C.A., "The SMARTS spectral irradiance model after 25 years: New developments and validation of reference spectra," Solar Energy, 187, 2019, pp. 233–253, Corrigendum, Solar Energy, 236, 222, pp. 906–907.
[2] Gueymard, C.A., "A reevaluation of the solar constant based on a 42-year total solar irradiance time series and a reconciliation of spaceborne observations," Solar Energy, 168, 2018, pp. 2–9.
[3] Gueymard, C.A., "Revised composite extraterrestrial spectrum based on recent solar irradiance observations," Solar Energy, 169, 2018, pp. 434–440.

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