Solar Spectral Irradiance: Air Mass 1.5

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Reference Solar Spectral Irradiance:
Air Mass 1.5

About the Reference AM 1.5 Spectra

American Society for Testing and Materials (ASTM) Terrestrial Reference Spectra for Photovoltaic Performance Evaluation

The photovoltaic (PV) industry, in conjunction with the American Society for Testing and Materials (ASTM) (http://www.astm.org/) and government research and development laboratories developed and defines two, and only two, standard terrestrial solar spectral irradiance distributions. The two spectra define a standard direct normal spectral irradiance and a standard total (global, hemispherical, within 2-pi steradian field of view of the tilted plane) spectral irradiance. The direct normal spectrum is the direct component contributing to the total global (hemispheircal) spectrum. The current Standard Reference Spectra are both incorporated into a single document, ASTM G-173-03.

HISTORICAL NOTE : The reference spectra were first generated as separate standards, designated as E-891-82 and E-892-82 (for direct normal and global tilt, respectively.) As of June, 1999, ASTM Subcommittee G3.09 combined these two documents into a single standard "Standard Tables for Reference Solar Spectral Irradiance at Air Mass 1.5: Direct Normal and Hemispherical for a 37 Degree Tilted Surface" The relevant international standard is ISO 9845-1, 1992, based solely upon both E891 and E892. In January of 2003, the G159 standard was REVISED extensively, and REPLACED with G173-03. The older

standards E-891, E-892, and G159 are WITHDRAWN and NO LONGER AVAILABLE except as historical standards. Downloads are provided here for reference and comparison with the new G173 spectra.

The ASTM G173 spectra represent terrestrial solar spectral irradiance on a surface of specified orientation under one and only one set of specifed atmospheric conditions. These distributions of power (watts per square meter per nanometer of bandwidth) as a function of wavelength provide a single common reference for evaluating spectrally selective PV materials with respect to performance measured under varying natural and artifical sources of light with various spectral distributions. The conditions selected were considered to be a reasonable average for the 48 continguous states of the United States of America (U.S.A.) over a period of one year. The tilt angle selected is approximately the average latitude for the contiguous U.S.A.

The receiving surface is defined in the standards as an inclined plane at 37° tilt toward the equator, facing the sun (i.e., the surface normal points to the sun, at an elevation of 41.81° above the horizon)

The specifed atmospheric conditions are:

a) the 1976 U.S. Standard Atmosphere [b] with temperature, pressure, aerosol density (rural aerosol loading), air density, molecular species density specified in 33 layers

b) an absolute air mass of 1.5 (solar zenith angle 48.19°s)

c) Angstrom turbidity (base e) at 500 nm of 0.084 [c]

d) total column water vapor equivalent of 1.42 cm

e) total column ozone equivalent of 0.34 cm

f) surface spectral albedo (reflectivity) of Light Soil as documented in the Jet Propulaion Laboratory ASTER Spectral Reflectance Database (*http://speclib.jpl.nasa.gov*.)

(See description of US standard atmosphere at http://www.pdas.com/atmos.html .)

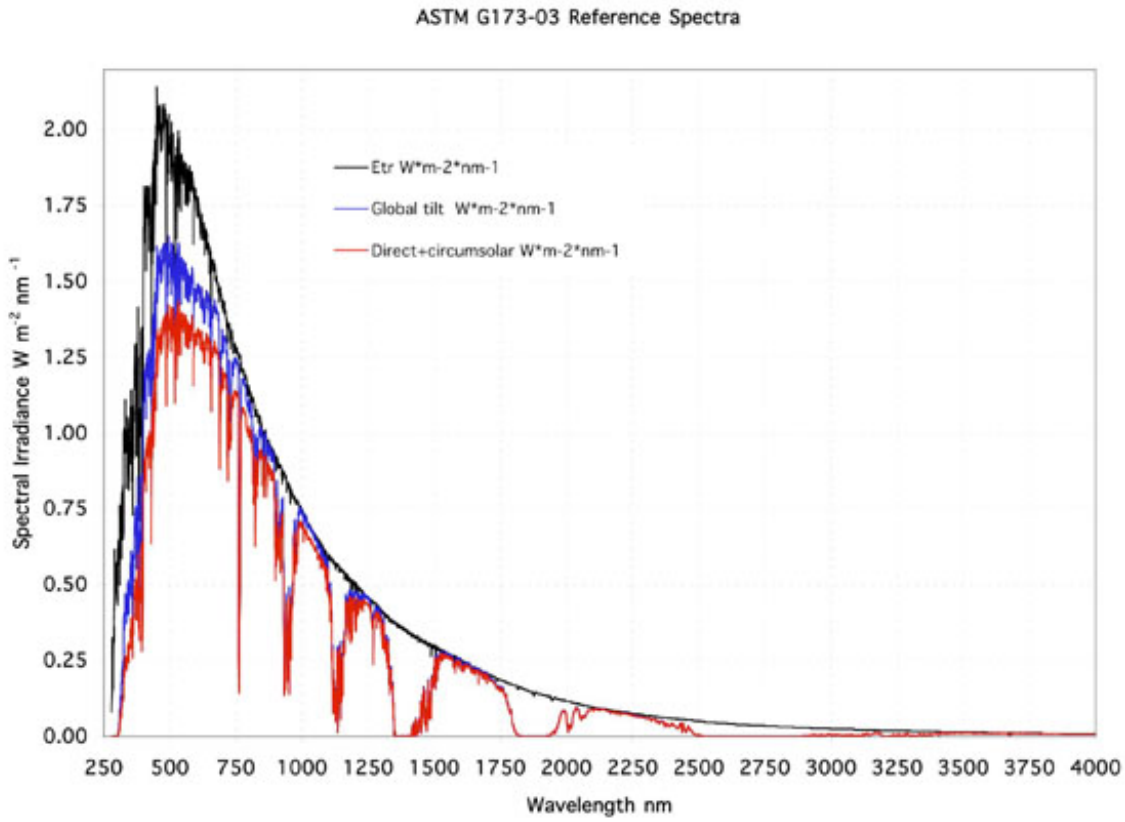
The spectra are modelled using the SMARTS2 (vesion 2.9.2) Simple Model for Atmospheric Transmission of Sunshine of Gueymard (See *Gueymard, 2001* and *Gueymard, 2003*).

The air mass zero (AM0), or extraterrestrial spectrum used to generate the current terrestrial reference spectra was developed by Gueymard, and is a sysnthesis of several AMO data sets (See *Gueymard, 2004* for an historical perspective.) Note the AM) spectrum used in conjunction with SMARTS to prodice the reference spectra is NOT the AM0 spectrum in ASTM E-490-99, as there are slight differences in bandpass and spectral resolution for the two spectra. (See our pages on the AM0 spectra at http://rredc.nrel.gov/solar/spectra/am0.)

The fields in the table Direct and Global 37 Deg Tilt: ASTM G-173 are wavelength in nanometers (nm), the (Gueymard 2002) extraterrestrial spectral irradiance, Direct Normal Spectral Irradiance in W/sm/nm, and the Global Total Spectral Irradiance, (W/sm/nm) on the 37° sun facing tilted surface for the atmospheric conditions specifed above:

To convert nanometers to μm, divide by 1000. To convert W/sm/nm to W/sm/μm, multiply by 1000.

A plot of the two distributions is shown here:



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NOTES

a To obtain a copy of ISO 9845-1, 1992 contact the International Organization for Standardization (ISO) at http://www.iso.ch/.

b The 1976 US Standard atmosphere used in the production of the modeled spectra:

> United States Committee on Extension to the Standard Atmosphere, "U.S. Standard Atmosphere, 1976", National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, United States Air Force, Washington D.C., 1976.

c The 0.084 aerosol optical depth (AOD) selectred for the G173 Standard is based upon study of the correlation between Direct Beam and 1000 W/m^2 Global Tilted broadband data in the Southwest U.S. (chosen as a likely deployment area for concentrating photovoltaic collectors.) (See Myers, et al., 2000a; Myers, et al., 2000b.)
For more information contact Keith Emery at Keith.Emery@nrel.gov

Please send questions and comments to the Webmaster.

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