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Broadband Solar Radiometry and Applied Measurement Techniques

January 29, 2009
Although the sum of the DNI and Global Diffuse values between both slides are within 35 W/m², GSI values differ by 158 W/m² as a function of cos Z of the incoming DNI signal.
Constituent GSI Radiation Components

Above plot depicts near perfect clear sky conditions with sustained daily DNI levels at NREL-SRRL, Golden CO.
Above plot depicts overcast broken sky conditions with high mid day Global Diffuse values at NREL-SRRL, Golden CO
POA (Plane of Array) Irradiance

**Solar Resource Assessment:** Long-term Global Solar Insolation measurements are applicable and useful for solar radiation resource assessment (standardized method).

**PV & ST Energy System Validation:** Reception angle of the received DNI and Global Diffuse irradiance significantly impact energy output of PV and ST energy systems. Hence total Global Insolation, Direct Insolation and Global Diffuse Insolation measurements may not be the optimal mode of measurement due to difference in reception angle between global horizontal and the reception angle of the applied solar renewable technology.

**Note:** Reflected DNI ground contribution on PV and ST system output is a function of ground surface albedo.
Diffuse sky-field energy distribution and spectral distribution vary with orientation of the applied PV or ST technology, relative to the conventional global horizontal plane. Often a POA mounted pyranometer is optimal for quantifying diffuse sky-field irradiance contribution on non-horizontal flat plate systems.
Normal Incidence Direct and Global Diffuse Solar Irradiance Measurement

ISO First Class thermopile type *pyranometer* for Global Diffuse, Total Global Insolation and POA (plane of array) irradiance measurement, from 0.3 to 2.8 µm.

ISO First Class thermopile type *pyrheliometer* for Direct Normal Incidence solar irradiance measurement, from 0.2 to 4.0 µm.

Autonomous two-axis *solar tracker* platform, for Normal Incidence Direct, Global Diffuse, Global Solar Insolation and POA (plane of array measurement.)
The above plots illustrate shifts in instrument sensitivity over varying solar elevation angle for two different pyrheliometer models. Ideally a pyrheliometer should exhibit consistent behavior and minimal slope effect independent of solar elevation. The plot left illustrates asymmetric behavior over varying solar elevation.
**Thermopile:** Operates on a temperature differential measurement principle ($\Delta t$). Detector generates linear voltage signal proportionate to induced solar heat load (ISO-9060 compliant technology).

**Photodiode:** Generates current signal proportionate to short-wave radiant flux. Shunt resistor generates a measurable voltage signal (NOT ISO-9060 compliant).
Thermopile and Photodiode radiometer Spectral Response

- Thermopile radiometers offer near true solar spectral response function
- Thermopile radiometers are non-spectrally selective (NOT the case w/photodiode models)
- Thermopile radiometers are suited for ST technologies (NOT the case w/photodiode models)
- Photodiode pyranometer are not WMO or ISO-9060 compliant (NO standardized calibration)
Alternative Instrument Approaches for Deriving DNI & Global Diffuse

**Multi-thermopile radiometer:** employs fixed shading geometry under dome. Sensor processes multiple detector output signals onboard and estimates Global Diffuse, Direct and total Global Insolation. Limiting factor is the black-box data processing approach, increased uncertainty on Global Diffuse measurement, lack of local support.

**Rotating shadow-band radiometer:** sound in theory but limited in accuracy and stability due to silicon photodiode pyranometer: spectral mismatch errors from shade to unshaded mode, sensitivity drift of photodiode and diminished directional response at low solar elevation.
Radiometer Response Time Vs. Photovoltaic Response

Response times of thermopile radiometers are quite varied from one manufacturer and one model type to the next. The more synchronous the response time between the DNI sensor (pyrheliometer) and PV the better.

- 1/e signal response: 63% of full response (e.g. Eppley)
- ISO and WMO state response: 95%
- Full instrument response: expressed as 99%