PV*SOL® Is the average photon energy (APE) a suitable measure to describe the uniqueness of solar spectra?

The average photon energy (APE) is often used to characterize solar spectra. Being a single value, that energetically averages a solar spectrum to a mean value, it is easier to use in scientific research in the field of photovoltaics than a whole array of values for a full spectrum.

1. Uniqueness of spectra with equal APE
   - The APE is calculated for IEC 60904 standard spectrum of AM1.5
     \[ \text{APE} = \frac{\int E_{\lambda} d\lambda}{\int \lambda E_{\lambda} d\lambda} \]
   - APE of IEC 60904 in the range of 370nm to 1000nm equals to 1.91eV
   - Measured spectra of equal APE of (1.91±0.002) eV are compared
   - Significant deviations of measured spectra to AM1.5
   - The APE is not a suitable measure to describe the uniqueness of solar spectra

2. Impact on PV
   - The impact of the APE on two electrical parameters is analysed
   - The variation of the relative MPP current
     \[ \Delta_{\text{MPP,rel}} = \frac{I_{\text{MPP,rel}} - I_{\text{MPP,STC}}}{I_{\text{MPP,STC}}} \]
   - The variation of the relative efficiency
     \[ \Delta_{\text{eff}} = \frac{\eta_{\text{rel}} - \eta_{\text{STC}}}{\eta_{\text{STC}}} \]
   - The impact is compared with another spectral indicator, the spectral weighed factor, that takes into account the EQE of the module
     \[ SWF = \frac{\sum E_{\lambda} \cdot EQE_{\lambda}}{\sum E_{\lambda} \cdot \frac{\lambda}{2}} \]
   - APE shows good indication for aSi modules, but fails for cSi.
   - SWF shows good indication for both aSi and cSi modules

Conclusion
An analysis of the uniqueness of spectra with equal APE has been conducted on the basis of high resolution measurements at HTW Berlin. On the basis of relative spectral deviations it could be shown that the APE cannot be considered a unique identifier for individual spectra.
A second analysis has been conducted to investigate the influence of the APE on electrical parameters of solar cells. It could be shown that the APE is a viable indicator for electrical parameters of aSi modules, but fails for cSi based modules. The overall results for the SWF have featured a higher quality for both aSi and cSi modules.