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# TOWARDS STANDARDIZED GENERATION OF BSDF DATA DESCRIBING COMPLEX FENESTRATION SYSTEMS

**Summary**

Well-informed design decisions are required to tap the full potential of daylight in buildings to improve occupant's health, well-being, and satisfaction, as well as to reduce energy consumption for artificial lighting and cooling. These are hindered by the current lack of standardized methods for modelling advanced daylighting and solar shading systems, which are characterized by their irregular light scattering properties. Transmission through and reflection off such optically complex fenestration systems are described for each pair of incident and outgoing, scattering direction by the Bidirectional Scattering Distribution Function (BSDF). While tabular BSDF data have been called for in ISO/CIE 10916:2024, the lack of a corresponding standard for the generation of such data is problematic. This finding contributed to the ongoing development of ISO/CIE CD 25176, which formulates a workflow from data-collection through validation to data provision. The future standard should foster the availability of reliable and comparable BSDF data.

*Keywords: Bidirectional Scattering Distribution Function BSDF, gonio-photometry, standardization, daylighting, solar shading*

*Field of application for the findings: Provision of BSDFs for building performance simulation*

*Addressed audience: Testing laboratories, building scientists, engineers*

## 1. Introduction and background

Good daylighting in buildings is essential for occupants' well-being and health, as daylight regulates the circadian rhythm, promotes concentration and reduces the risk of health problems such as eye strain or sleep disorders (Knoop et al., 2020). Daylight and view connectivity are central factors for occupant satisfaction (Jamrozik et al., 2019; Lee et al., 2022). At the same time, the optimal use of daylight contributes to energy efficiency by reducing the need for electric lighting and the proper management of solar gains enables minimization of cooling and heating demands. This helps to support sustainable buildings, which offers both ecological and economic benefits (Bashir et al., 2024; IEA SHC Task 61, 2019).

To make full use of these potential benefits is challenging, since continuously changing daylight conditions must be taken into account at all scales of building design, e.g., in early decisions on massing, the layout of floor plans, and the design of building envelopes. Building standards stipulate when and how designers and architects must follow standardized methods and regulations to meet requirements for daylight supply and shading. While these standards often assume standard conditions, e.g., normal incidence under idealized conditions, more advanced methods to characterize angle-dependent, solar-optical properties (transmittance, absorptance, reflectance) are well established for transparent glazing. Such advanced, standardized methods do not exist for so-called complex fenestration systems (CFS), i.e., light scattering, shading and daylighting systems. Methods for characterizing CFSs, referred to in European (EN 14500/14501) and international standards (ISO52022-1/3:2017-06), are simplified in that they are based on selected normal or hemispherical transmittance and reflectance measurements. This can cause significant errors in the assessment of daylighting and indoor environmental quality, e.g., visual comfort (Wang et al., 2023), as well as for solar gains-related impacts on building energy demand. This in turn renders the objective evaluation of the impact on energy demand, solar distribution, daylight supply, visual comfort, and other aspects of building performance almost impossible. In a comprehensive summary, De Michele et al. (2018) describe why simplified normative methods are often no longer sufficient for building performance simulations and why so-called bidirectional scattering distribution functions (BSDF) are now frequently used for optical modelling.

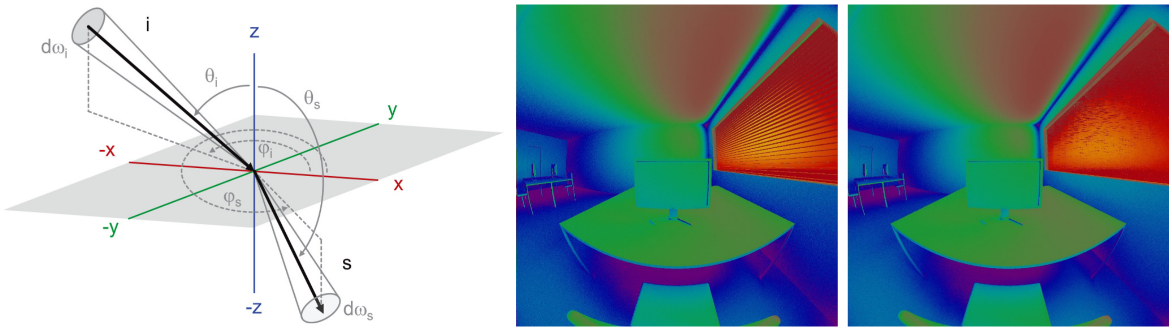


**Fig. 1:** The BSDF is a general formulation for reflection and transmission as light transport between fractional solid angles $d\omega_i$ and $d\omega_s$, i.e., as a function of incident and outgoing directions $\theta_i$, $\phi_i$ and $\theta_s$, $\phi_s$ (left). The falsecolor images show the luminance distribution in a room as derived from simulations using the geometry of venetian blinds (center) or using the corresponding BSDF representation (right).

BSDFs – describing the angle-dependent scattering properties of a surface (Stover, 2012), or in the special case of a CFS (cf. Fig. 1) – have found their way into numerous daylight simulation tools. Further, the newly revised version of the standard ISO/CIE 10916:2024 that describes methods for the calculation of the impact of daylight utilization, now includes the so-called three-phase method, which explicitly requires BSDF data. Such BSDF data are therefore essential in planning practice in simulations and normative procedures, but there is no standardized method for creating such data.

## 2. Towards a New International Standard

In order to close the gap in the standardization, the International Organization for Standardization (ISO) and the International Commission on Illumination (CIE) launched the project ISO/CIE CD 25176 “Light and lighting - Daylight in buildings - BSDF data generation for complex fenestration systems” in 2024 as a joint effort. The scope of this project is described as follows. *“This document specifies procedures (a) for characterizing angle-dependent transmittance and reflectance properties of complex fenestration systems (CFS) and (b) for generating tabular BSDF data sets from the measured or simulated data for use as input to simulation tools.”* (ISO/CIE CD 25176).

The targeted standard aims to ensure robust, comparable BSDF data as input for high-quality daylighting simulations, solar energy assessments, and for the method in ISO/CIE 10916. In terms of content, the standard is strongly aligned with a white paper prepared in 2021 by experts collaborating in the IEA SHC Task 61 / EBC Annex 77 (Geisler-Moroder et al., 2021). It differentiates complex fenestration systems (CFS) into microscopic and macroscopic systems. Microscopic systems are defined to be directly measurable with goniophotometers (e.g., roller shade fabrics, prismatic films), while macroscopic systems area assumed to be too large or irregular for direct measurement (e.g., venetian or honeycomb blinds). For macroscopic systems, the standard recommends virtual, i.e., simulation-based goniophotometry using geometric 3D models and material specifications derived from physics-based models or from measurements. The core focus is the end-to-end workflow: data collection, conversion to suitable BSDF discretizations, provision in XML-based formats, interpolation, optional validation through measurements of direct-hemispherical transmission, and embedding of proxy geometry. The standard addresses uniform versus peaky scattering, the importance of instrument signature, and incidence-direction sampling guided by sample symmetry. Informative annexes describe angular bases, interpolation methods, validation procedures, and include example workflows for fabric shades and venetian blinds. Rather than duplicating measurement standards, it aims to harmonize methods and outputs for simulation and normative use.

## 3. Discussion and Outlook

The previous work in IEA SHC Task 61 / EBC Annex 77 that led to the white paper (Geisler-Moroder et al., 2021) defined a clear pathway (Geisler-Moroder et al., 2024) that enabled rapid consensus for a first draft of ISO/CIE CD 25176. The standard is currently in the development phase and will be available for comment as a draft international standard (DIS) in spring 2026. All experts in the field of BSDF data generation and interested parties are invited to participate and provide feedback via their respective national committee of ISO TC 274 or their national CIE committee.

The proposed standard extends daylight assessment and simulation standards to include reliable, comparable BSDF data generation, supporting both CFS development and application. It guides laboratories in parametrizing BSDF procedures based on intended use and CFS characteristics, benefiting industry, planners, and consultants, and reducing documentation effort through consistent terminology and practical examples.

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