Characterization of advanced daylighting systems and combined lighting and thermal simulation

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Abstract

As the interface between interior and exterior spaces, the façade plays a key role for the thermal and visual conditions in buildings. Advanced daylighting systems should fulfill various and in parts contradictory requirements: they must provide sufficient and adequately distributed natural lighting, avoid visual discomfort (glare) while allowing visual contact to the exterior, provide solar gains for heating in winter and protect from high radiation against overheating in summer. Integrating these functionalities often results in products which are more complex than conventional sunshading systems and thus are often not properly characterized and cannot be applied in standard design workflows. We present approaches for the characterization of advanced daylighting systems and introduce DALEC, a simplified tool for combined lighting and thermal simulations that can account for such systems. A comparison between DALEC and TRNSYS proves that the simplified approach is adequate for integrated simulations in early design phases.

1. Characterization of advanced daylighting systems

Windows and glazing units are well characterized by visual and solar light transmission values as well as the solar heat gain coefficient and the U-value. Standardized values do however not exist for daylighting systems, which in turn makes objective comparisons of various systems almost impossible. Moreover, a standardized characterization is necessary to be able to include daylighting systems in lighting and thermal simulations. Simplified approaches, which – at least partially – work for conventional systems as screens or blinds, found their way into European standards [1], but these approaches are not sufficient for advanced systems.

Already in 1994, Klems [2] proposed to calculate the solar heat gain coefficient (SHGC) of fenestration systems based on a 145x145 discretization of the incoming and outgoing hemispheres. This subdivision scheme, which yields approximately equal irradiances for each patch at constant radiance, is also applied in programs as WINDOW7 [3] or RADIANCE [4] to describe a system's bidirectional scattering distribution function (BSDF), i.e. the geometrical-optical properties of the system. Using the BSDF it is possible to efficiently integrate daylighting systems in lighting simulation software, even without having information about the system geometry or its detailed material properties. Klems' subdivision of the hemisphere where every patch corresponds to an average solid angle of 0.043sr (i.e. a cone with 2 x 6.7° apex angle) has to be handled with care. For example, when dealing with highly specular systems that react sensitive to changes in incident directions (e.g. daylight redirecting systems), this representation might lead to significant errors. To overcome this, a variable resolution BSDF approach has been introduced by Ward et al. [5] that enables high accuracy via a fine resolution for critical regions of the BSDF while providing a coarse structure with little data for smooth regions. With this approach also improved annual simulations including complex fenestration systems can be realized at high accuracy (Lee et al. [6]).

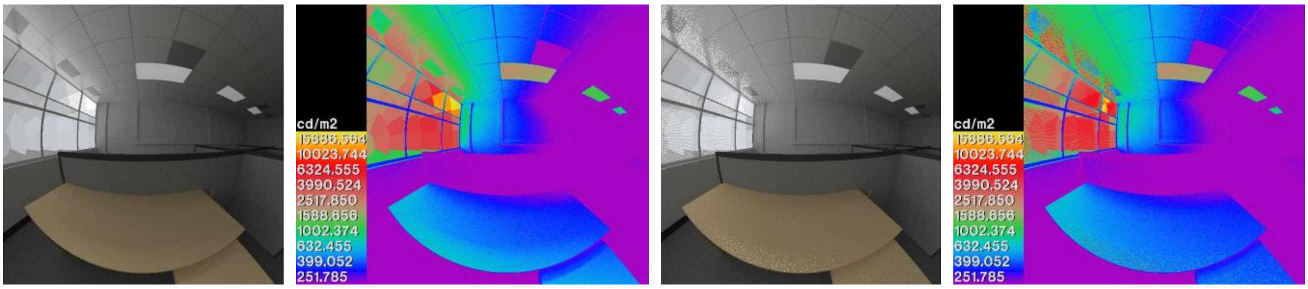

Figure 1: Result from simulation with BSDF in Klems resolution (left) and with variable resolution BSDF for a more detailed calculation of the direct sun part (right).

In the Subtask C “Design support for practitioners (Tools, Standards, Guidelines)” of the ongoing IEA SHC Task 61 / EBC Annex 77 “Integrated Solutions for Daylighting and Electric Lighting” [7], international experts are working on an approach for the standardization of BSDF daylight system characterization.

While the BSDF of the system is used to describe the optical properties of a complex daylighting system, the SHGC characterizes its thermal properties including the solar transmission and the secondary heat flux. At Bartenbach two-dimensional angular dependent SHGCs of daylighting systems can be measured. With this representation, the thermal behaviour of advanced daylighting systems can be considered in annual building simulations.

Figure 2: SHGC measurement device at Bartenbach, Austria.

2. Integrated lighting design for daylighting, electric lighting and user comfort

With DALEC – “Day- and Artificial Light with Energy Calculation” (www.dalec.net) [8] an online concept evaluation tool for lighting designers, architects, building engineers and building owners has been developed by Bartenbach together with Zumtobel Lighting and the University of Innsbruck [9]. Although easy to use, the software accounts for the complex thermal and lighting processes in buildings and allows a simple evaluation of heating, cooling and electric lighting loads. Not only energy, but also user behavior is considered and visual and thermal comfort is evaluated (glare, overheating frequency). This novel and innovative, holistic approach makes sustainable and energy efficient building design possible for new buildings as well as refurbishment. Contrary to other simplified tools for early design phases, DALEC allows to include complex daylighting systems through BSDFs and angular dependent SHGCs in the calculations. With this the resulting daylighting – and thus also the required electric lighting – for the space can be considered with higher accuracy.

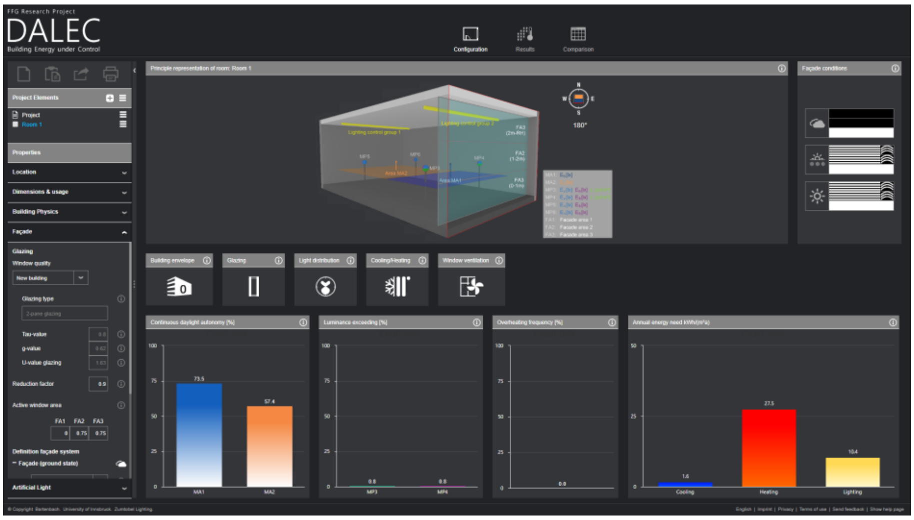

Figure 3: User interface of the DALEC web tool.

3. Comparison of a simplified and a complex simulation approach

Within the IEA SHC Task 56 “Building Integrated Solar Envelope Systems for HVAC and Lighting” [10], a reference office room has been defined that provides a well-defined setting for simulation comparisons [11]. This setup was used to compare the DALEC simulation software against the well-established building simulation software TRNSYS [12].

The results in Figure 4 show a good agreement between DALEC and TRNSYS. The remaining differences in the heating and cooling demands are due to different modeling approaches of e.g. schedules for internal gains, ventilation properties, active façade areas or the thermal capacity of the building. Details of the comparison are presented in [13].

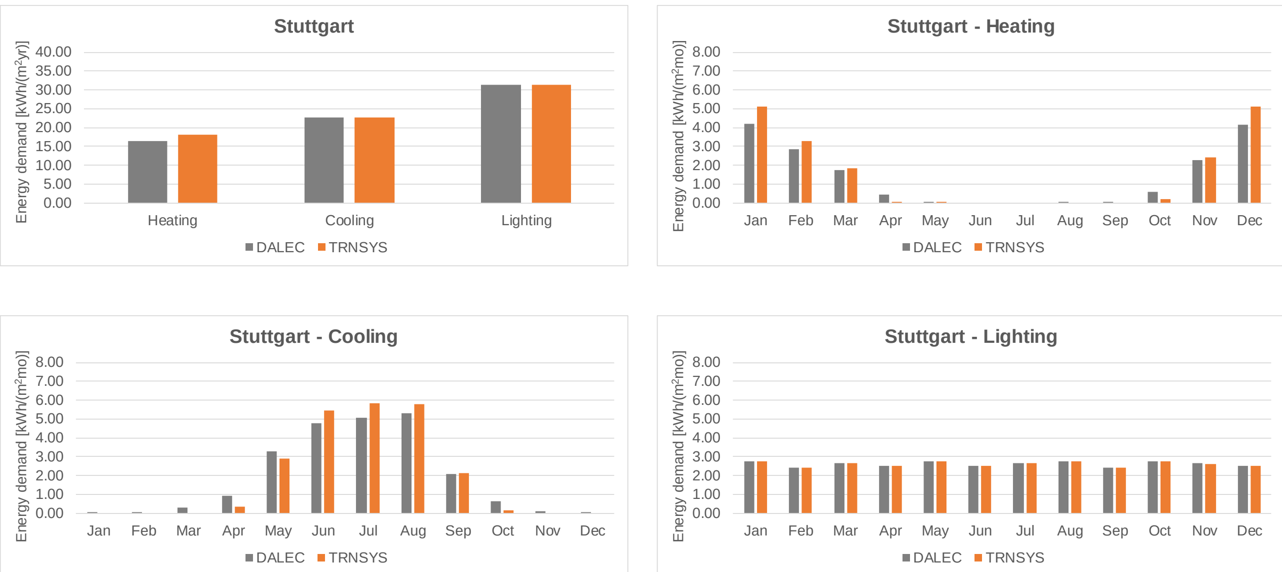

Figure 4: Results of comparison between DALEC and TRNSYS for climate Stuttgart.

4. Acknowledgements

The TRNSYS simulations for the comparison in the course of the IEA SHC Task 56 were performed by Matteo D'Antoni from EURAC, Italy.

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5. References

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