A SPECIFIC BUILDING SIMULATION TOOL FOR THE DESIGN AND EVALUATION OF INNOVATIVE FENESTRATION SYSTEMS AND THEIR CONTROL

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Functions of windows

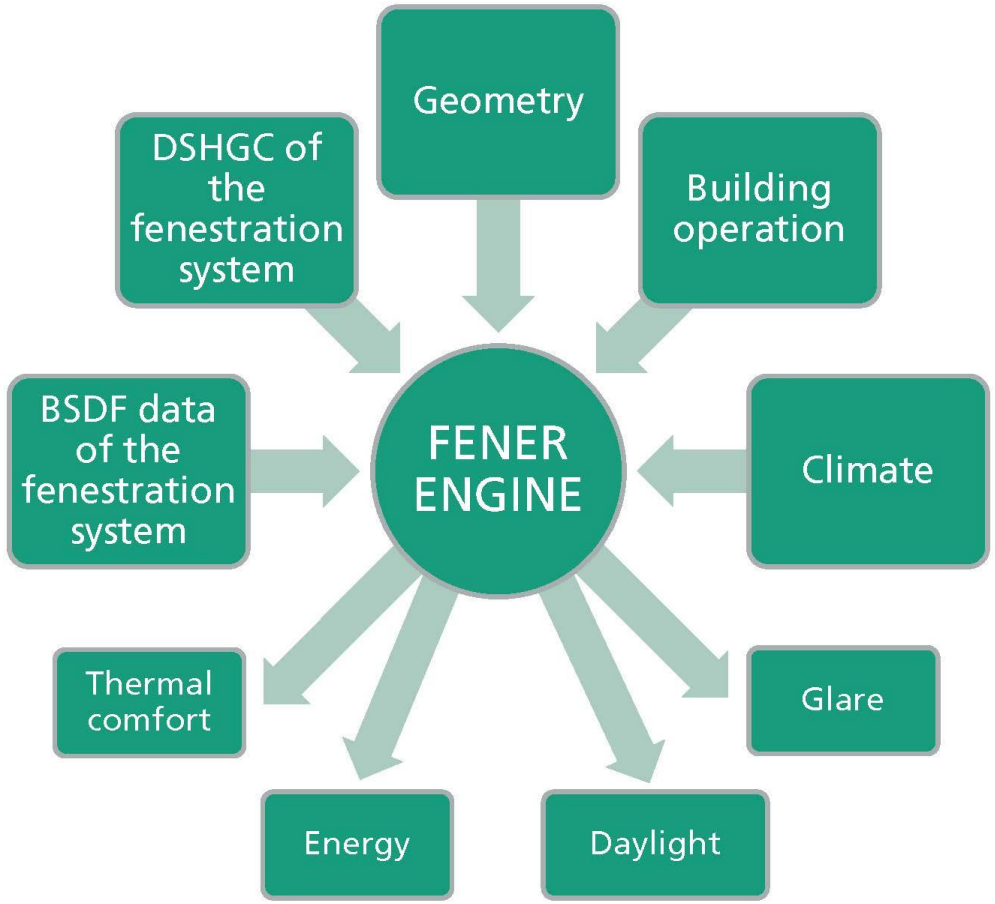
Crucial for buildings to be comfortable and energy efficient

- Daylight provision
- Glare protection
- Solar heat gain management
- Thermal management
- Visual contact
- Color rendering
- Energy generation
- Aesthetics
- …

These functions oppose each other… aargh!

The Fener tool

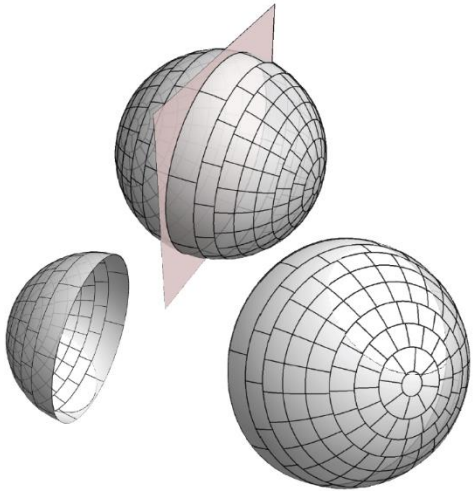
- A specific building simulation tool for the design and evaluation of innovative fenestration systems and their control.
- Simulates advanced control strategies -> time-step coupling between daylighting and thermal problems.
- Implements models for the complex thermal and optical processes that occur in fenestration systems.
- Implements state-of-the-art models for visual and thermal comfort.
- Fener is a OpenSource software copyrighted and distributed by the Fraunhofer ISE https://github.com/bbuenoun/Fener



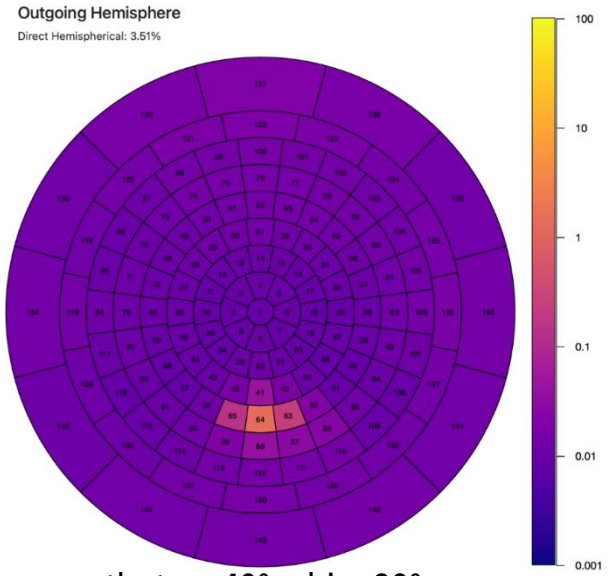
B. Bueno, A. Sepúlveda. A specific building simulation tool for the design and evaluation of innovative fenestration systems and their control. IBPSA Building Simulation Conference, Rome 2-4 September, 2019.

Input parameters
Optical properties

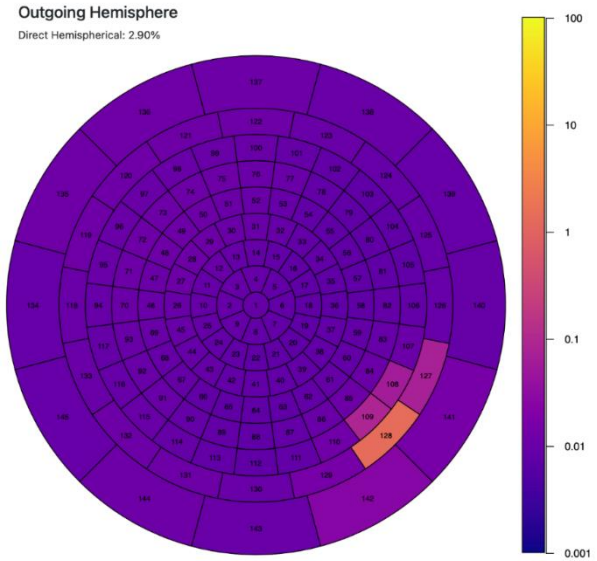
- Bi-directional scattering distribution functions (BSDF) describe the spatial distribution of light scattered by a sample in transmission and reflection for different incidence angles.
- It can be determined experimentally with a goniophotometer.
- Datasets are becoming available in widely-used databased (e.g. IGSDB)



McNeil, Radiance Workshop 2014



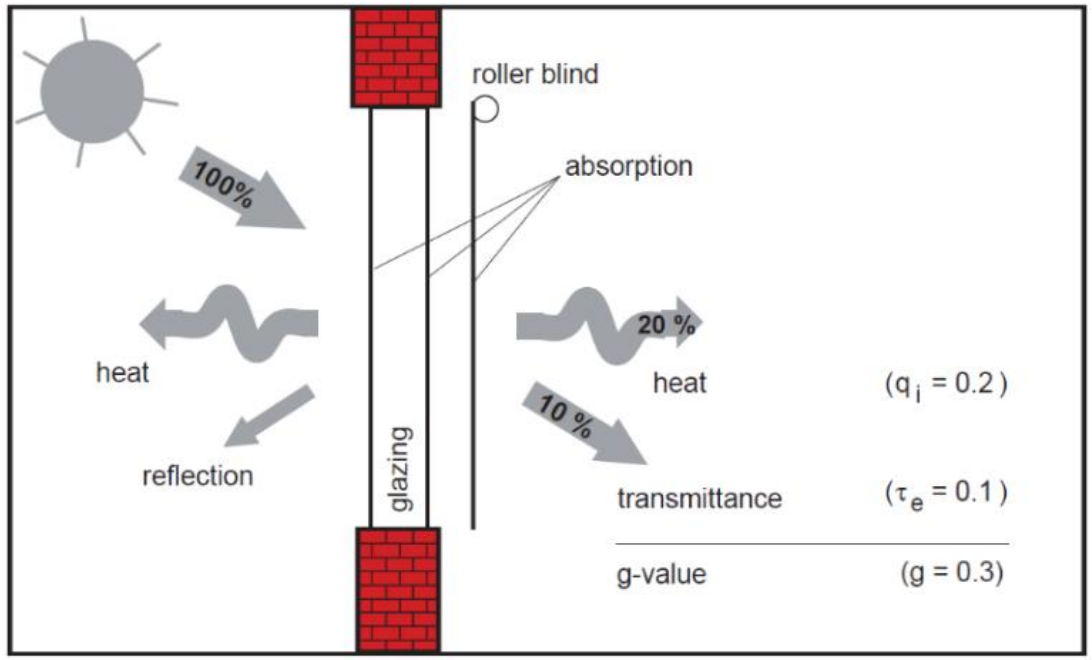
theta = 40°, phi = 90°



theta = 72°, phi = 45°

Input parameters
Thermal properties

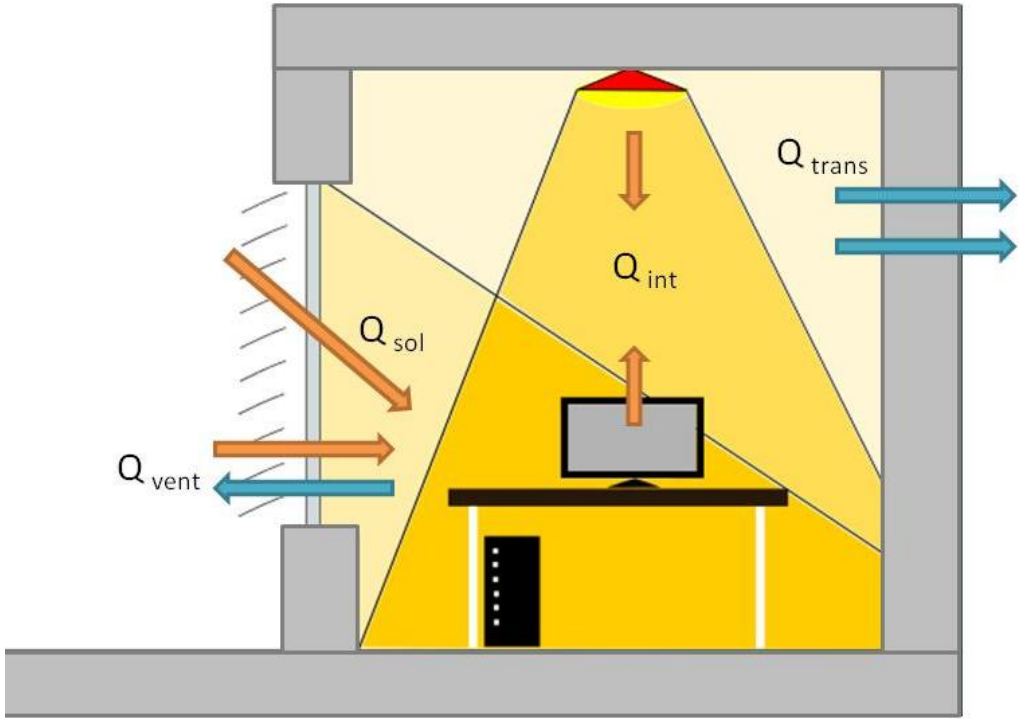
- U-value
- DSHGC – Directional Solar Heat Gain Coefficients
  (angle-dependent g-values)



Solar calorimeter for g-value determination of facade components at Fraunhofer ISE

Building physics
Thermal module

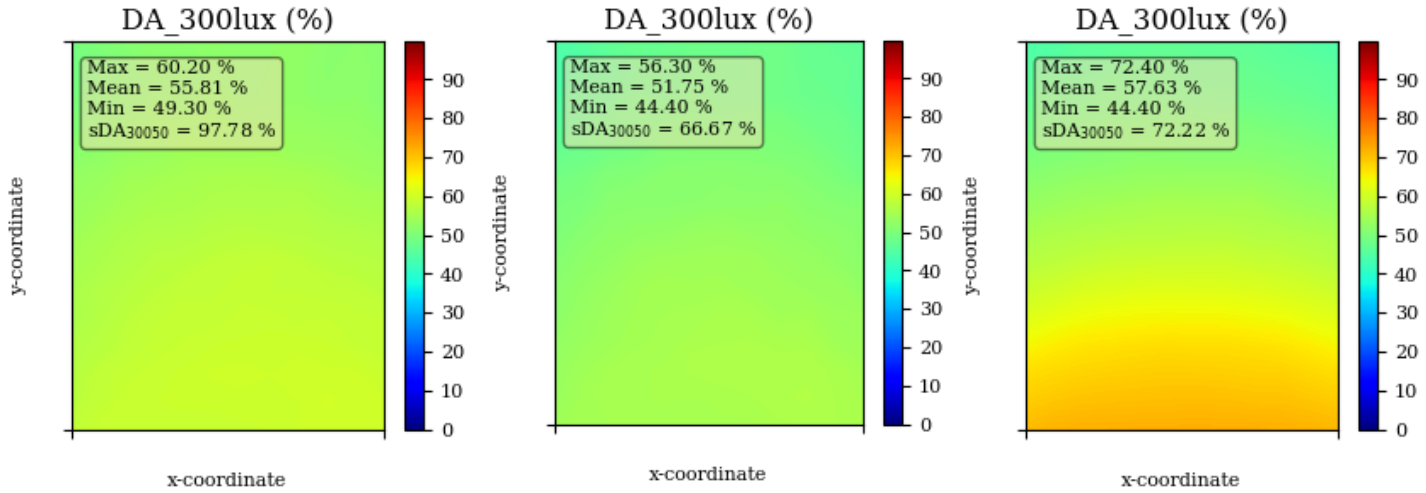
- Energy balance method to calculate the thermal conditions in the room.
- Transfer functions for the transient heat conduction through opaque elements.
- The three-phase method to calculate the transmitted solar radiation.
- The Kuhn2011 model to calculate the heat transfer through the fenestration systems



Bueno, B., J.-M. Cejudo-Lopez, and T. E. Kuhn (2017). A general method for the evaluation of the thermal impact of complex fenestration systems in building zones. Energy and Buildings 155, 43 - 53.

Building physics
Daylighting module

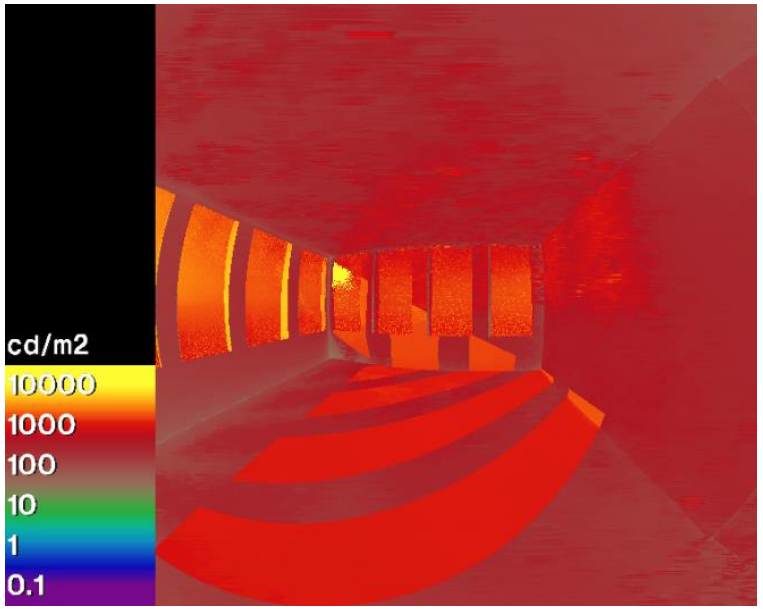
- The three-phase method is suitable for annual daylighting calculations.
- It is based on matrix algebraic methods, where the light flux from the sky to indoor points of interest is divided into several contribution coefficient matrices.
- The method uses low-resolution BSDF datasets (Klems).
- The method is being included in building simulation tools and standards (e.g., ISO 10916).



Bueno B., J. Wienold, A. Katsifaraki, T.E. Kuhn, Fener: a Radiance-based modelling approach to assess the thermal and daylighting performance of complex fenestration systems in office spaces, Energy Build. 94 (2015) 10–20

Building physics
Glare module

Metrics	Glare contributions	Computational efficiency	Facade representation
Vertical illuminace at eye level	• Light saturation at eye level	• Three-phase method (very fast)	• Low-resolution Klems BSDF
Daylight Glare Probability	• Light saturation at eye level • Contrast ratio reduction due to glare sources in the field of view	• Luminance map of the field of view	• Geometry of fenestration system • High resolution tensor tree BSDF • Low-resolution BSDF + peak extraction



Abravesh M., B. Bueno, S. Heidari, T. E. Kuhn (2019). A method to evaluate glare risk from operable fenestration systems throughout a year. Building and Environment 160, doi.org/10.1016/j.buildenv.2019.106213.

Sepúlveda, A., Bueno B., Wang T., Wilson H.R.. Benchmark of methods for annual glare risk assessment. Building and environment 201 (2021), ISSN: 0360-1323. DOI: 10.1016/j.buildenv.2021.108006

Bueno B., Sepúlveda A., Maurer C., Wacker S., Wang T., Kuhn T.E., Wilson H.R.. Easy-to-Implement Simulation Strategies for Annual Glare Risk Assessments based on the European Daylighting Standard EN 17037. Proceedings of Building Simulation 2021, International Building Performance Simulation Association, Bruges, September 1-3, 2021.

The Fener tool
Applications

- Glare risk assessment for a certain facade technology and building application.
- Compliance with European Daylighting Standard EN 17037.
- Comparative design of façade systems.

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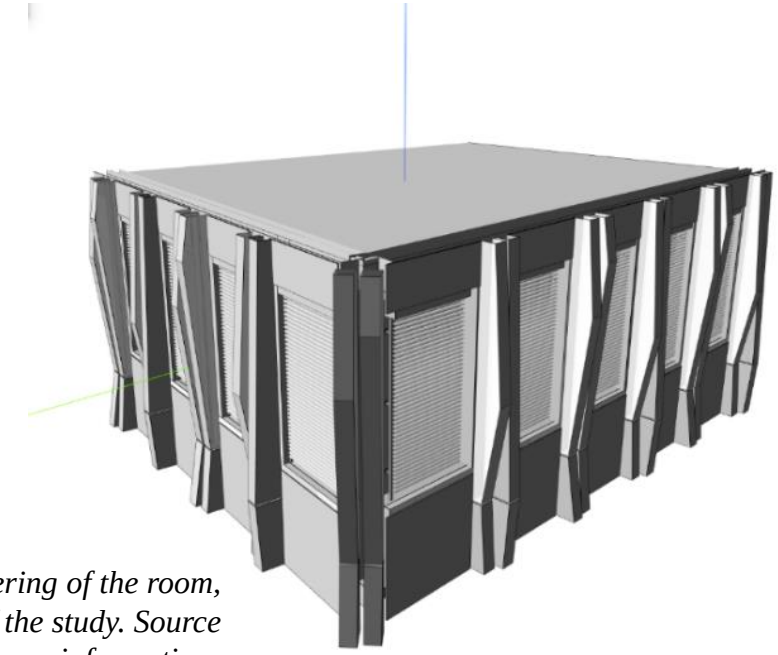
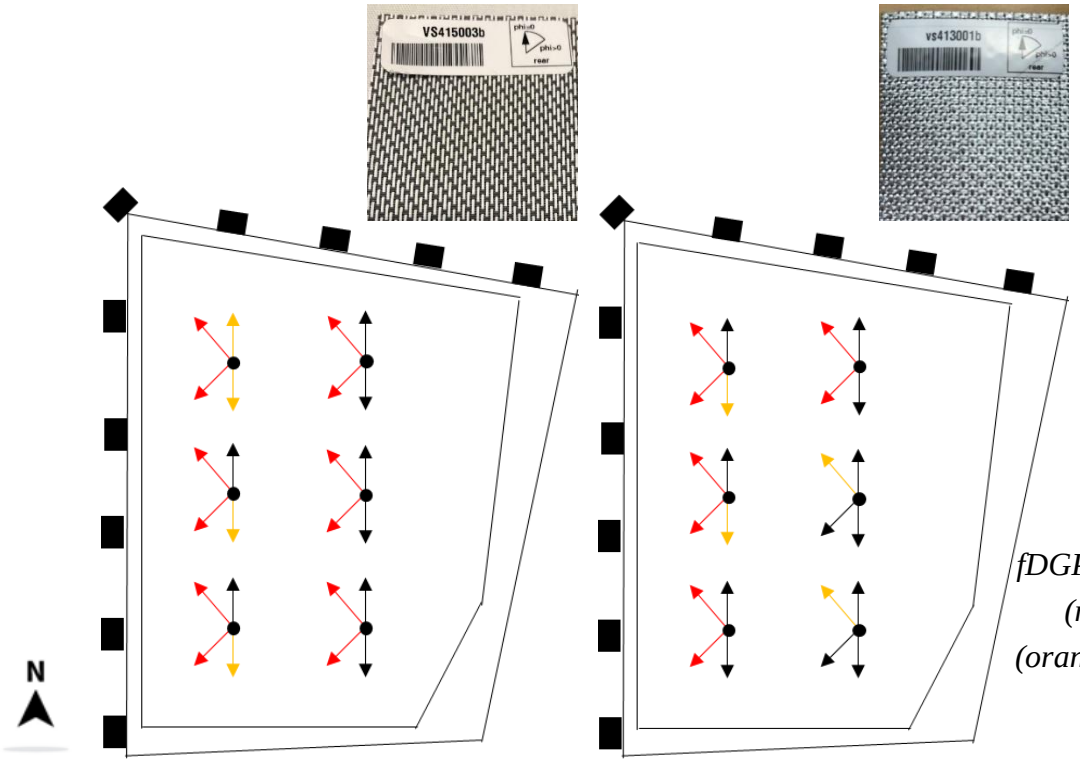


Rendering of the room, object of the study. Source of Radiance information: Ed Züblin AG



fDGPt greater than 5%.
(red) DGP_e = 0.45
(orange) DGP_e = 0.40
(left) fabric A
(right) fabric B

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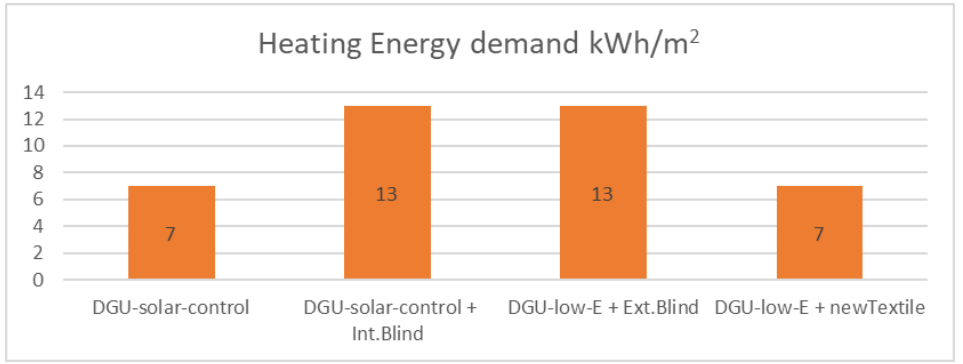

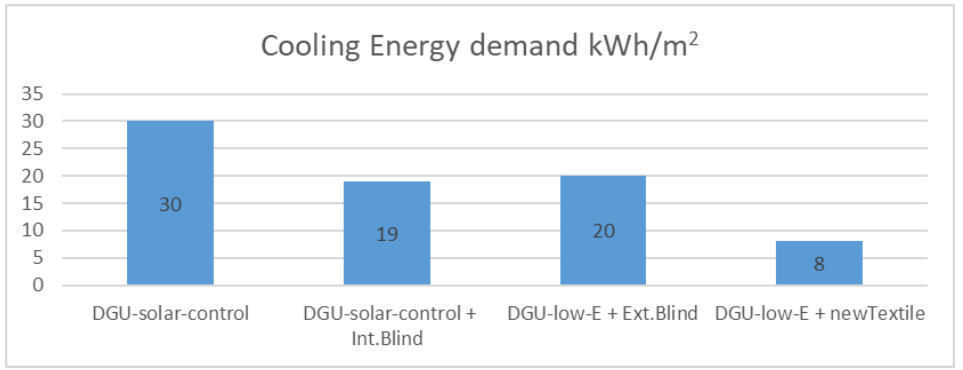

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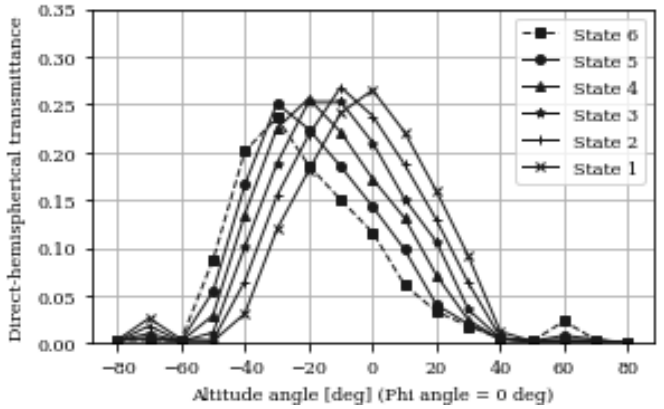
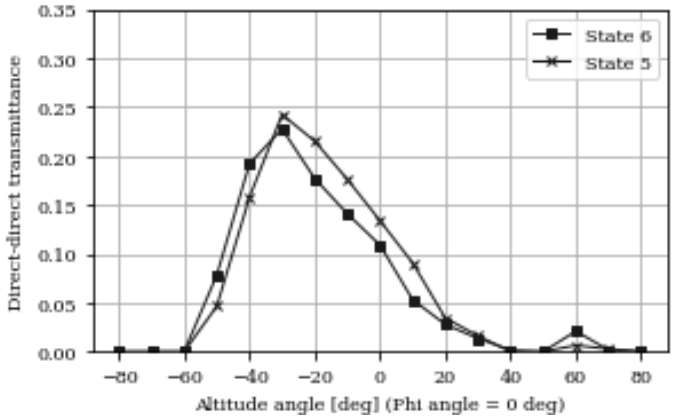
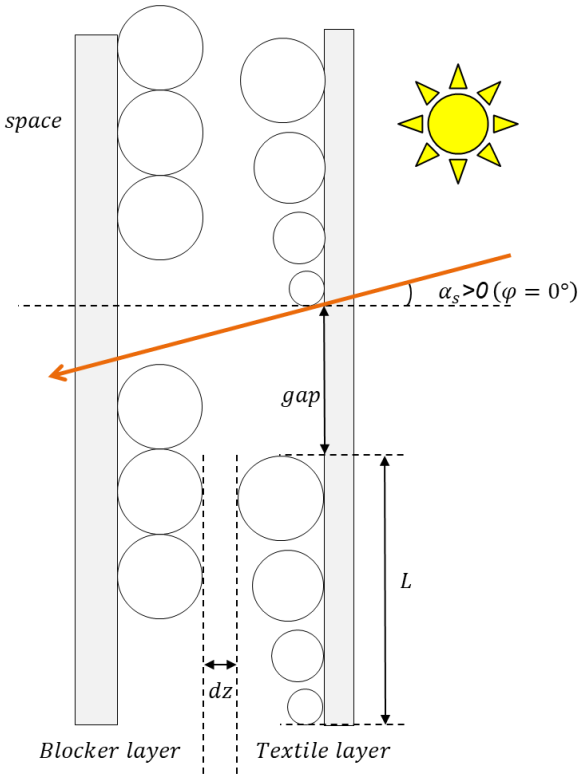
- Design of innovative products.







B. Bueno, H. R. Wilson, A. Sepúlveda, S. Sunkara, T. E. Kuhn, 2020. Simulation-based design of an angle-selective and switchable textile shading system. Building and Environment 184(1):107227. DOI: 10.1016/j.buildenv.2020.107227

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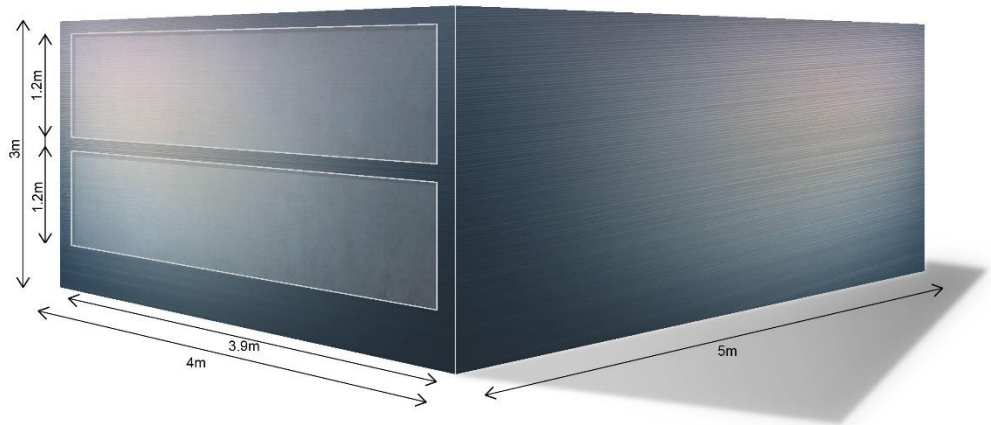

Advanced algorithm					
Max. vert. illu. >2700 lux	Max. vert. illu. >3500 lux	Room air temp. >23°C	Mean hor. illu. >2000 lux	Low. win. state	Upp. win. state
0	0	0	0	0	0
0	0	0	1	0	0
0	0	1	0	1	0
0	0	1	1	1	1
1	0	0	0	1	0
1	0	0	1	1	1
1	0	1	0	1	0
1	0	1	1	1	1
1	1	0	0	2	0
1	1	0	1	2	1
1	1	1	0	2	1
1	1	1	1	2	2
Basic algorithm					
0	0	-	-	0	0
1	0	-	-	1	1
1	1	-	-	2	2
0	0	-	-	2	2
1	0	-	-	2	2
1	1	-	-	2	2

A. Katsifaraki, B. Bueno, T.E. Kuhn, A daylight optimized simulation-based shading controller for venetian blinds, Build. Environ. 126 (Supplement C) (2017) 207–220

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- Glare risk assessment for a certain facade technology and building application.
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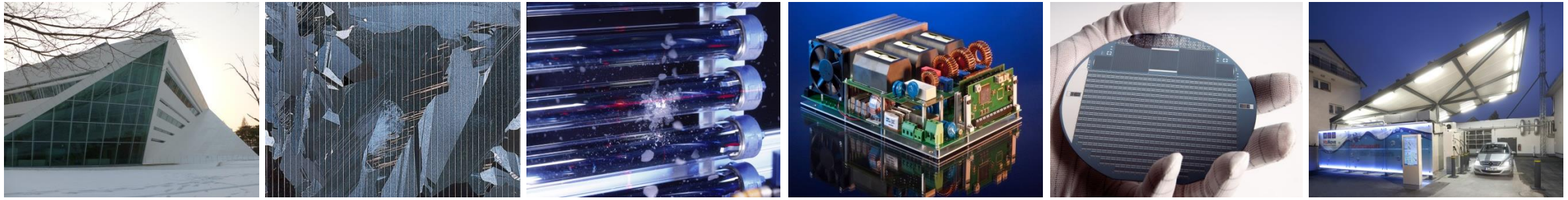
- Comparative design of façade systems.
- Design of innovative products.
- Development of advanced control strategies.
- Validation of new methods.

The Outdoor Testroom at Fraunhofer ISE (KONTINENT). The rooms are fully equipped with sensors for the evaluation of façade effects on the energy demand, thermal and visual comfort in buildings. The facility includes video cameras and smoke generation for the visualization of the air movement. The testrooms are placed on a rotatable structure, and thus different façade orientations can be investigated.

Thank you for your Attention!



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