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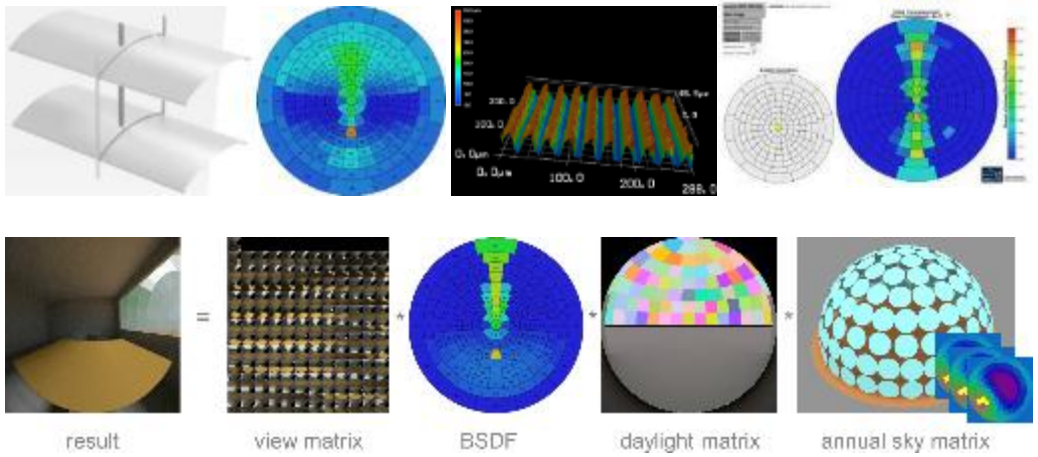
Reference Models for Comparing Simulation Tools to Evaluate Low-Carbon, High-Comfort Integrated Lighting

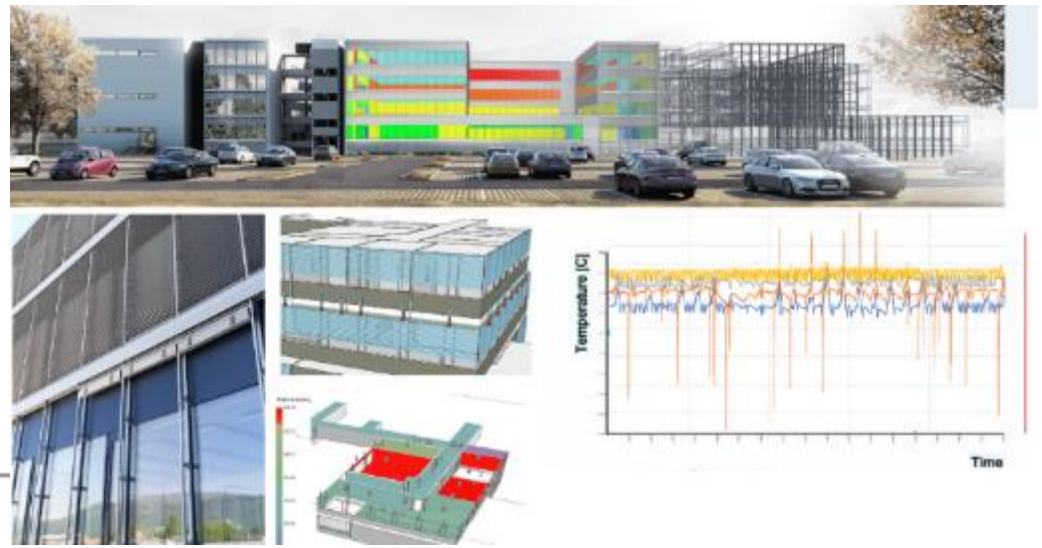
David Geisler-Moroder, Xuran Guo, Sascha Hammes, Christian Knoflach, Martin Hauer, Daniel Rüdisser, Zhen Tian

ISEC 2026 – 4th International Sustainable Energy Conference

Complex Fenestration Systems for Low Carbon Buildings
CFS4LowCarb

- Integrated daylighting and shading technologies in complex fenestration systems
- Comprehensive utilization technologies and analysis integrated with solar energy
- Evaluation of key daylighting/ shading and photovoltaic/thermal technologies





https://www.uibk.ac.at/en/energy-efficient-building/research/projects/cfs4lowcarb/

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SHC

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

TASK 70

Low Carbon, High Comfort Integrated Lighting

IEA SHC Task 70 / EBC Annex 90

Low Carbon, High Comfort Integrated Lighting

Task Manager: J. de Boer, Germany

Project duration: 1/2023-6/2026

Joint Work

Subtask A

Luo Tao, China
J. de Boer, Germany

Low Carbon Lighting and Passive Solar: Scenarios, Strategies, Roadmaps

Subtask B

B. Matusiak, Norway
M. Sarey Khanie, UK

Visual and Non-Visual User Requirements

Subtask C

D. Geisler-Moroder, Austria
Eleanor Lee, USA

Digitized lighting solutions
(Technology & Design Tools / Process)

Subtask D

Niko Gentile, Sweden
Natalia Giraldo Vasquez, Denmark
Justyna Martyniuk-Pęczek, Poland

Application and Case Studies

Joint Work

ST A: Laying the basis

extend the life cycle approach to integrated lighting solutions

data, methods, scenarios

ST B: Including the user

obtain real impact instead of hypothetical technical potential

visual/non-visual needs, user behavior models

ST C: The tech part

make lighting techs intelligent, connected, and fully mapped in design work

(day)lighting systems and controls, workflows, tools

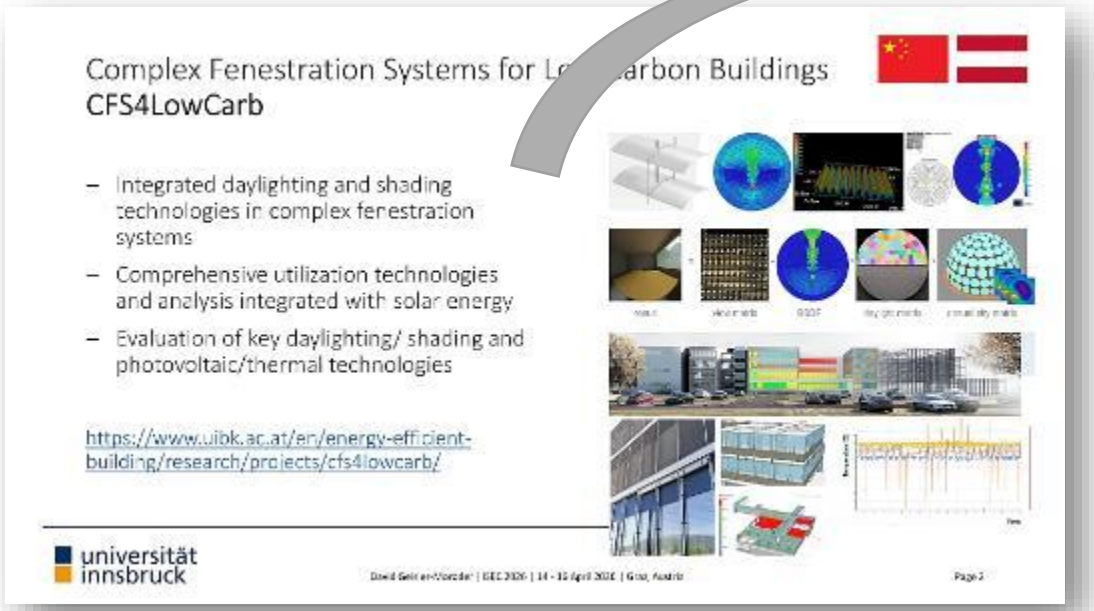
ST D: Evaluating and validating

test the methods and assess the real impact in example scenarios

case studies, guidelines, link to CIE

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Comparison of Simulation Tools



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Application and Case Studies

Joint Work

Comparison of Simulation Tools

- Simulation tools feature matrix (26 tools)
- Simulation tools summary document
- Reference rooms (simulation exercise)

	Applies to Software + = yes, o = partly, blank= no																										
	AtriaRAD	ALFA	AGI32	AM Tools	ClimateStudio	DIALEC	DesignBuilder	DIALux	DIALux+	DL-Light	DVIZ	ElumTools	frads	GB SWARE	Honeybee	IES VE	LARK	LightStanza	OpenStudio	OWL	PKPM	Radiance	RELUX	Sefaira	TRNSYS	Unreal Engine
SOFTWARE SUITED FOR																											
Lighting designers	+	+	+	+	+	+	o	+	+	+	+	+	o	+	+	o	+	+	o	+		+	+	+	o	o	
Architects	+	+	o	+	+	+	+	+	+	+	+	+	o	+	+	o	+	+	+	+	+	o	+	+		+	
Electric engineers	+	o	+		o	+	o	+	+			+		+	+	o			o			+	+	o			
HVAC engineers	o				+	+	+		+				+	+	+	+			+		+			+	+		
Building engineers/planners	+		o		o	+	+	o		+	+	o	o	+	+	+	+	o	+	+	+			+	+	o	
Researchers	+	+	o		+	+	+	o		+	+	o	+	+	+	+	+	o	+	+		+	+	o	+	+	
DESIGN PHASE																											
Suited for R&D	+	+	o		+		+	o				o	+	o	+	+	+	o	+			+	+	o	+	+	
Suited for early design	+	+	+	+	+	+	+	+	+	+	+	+	o	+	+	o	o	+	+	+	+	o	+	+	+	+	
Suited for detailed design	+	+	+		+		+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	o	+	+	
ELECTRIC LIGHTING																											
Illuminance values	+	+	+		+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+		+	
Luminance values	+		+					+				+	+	+	+	+	+	+	o	+		+	+	+		+	
Calculation of connected wattage	o	o	+		+	+	+	+	+			+	+			+			+	+		o	+	+	+		
Calculation of annual electricity consumption	o				+	+	+	+	+				+		+	+			+	+		o	+	+	+		
Import of luminaires (IES, Eulumdat, etc.)	+	+	+		+	o		+	+			+	+	+	+	+	+	+	+	+		+	+	+		+	
Data base of luminaires		+	+				o	+	+			+		+		+	o	o		o			+	o			

User-defined control strategies for daylight system
User-defined integrated control strategies for electric and daylight systems
Calculation of annual electricity consumption
VISUAL & NON-VISUAL EFFECTS
Reduced spectral simulations (3 channels)
Reduced spectral simulations (4-10 channels)
Full spectral simulations
Spectral models for electric lighting
Spectral sky models
Evaluation of α-opic irradiance
Evaluation of α-opic ELR
Evaluation of α-opic DER
Evaluation of α-opic EDI
Calculation of circadian stimulus CS
Electric lighting glare calculations (UGR, VCP, …)
Daylight glare calculations (DGP, DGI, …)
Calculation of light dose from electric lighting
Calculation of light dose from daylight
Occupant modelling beyond standard schedules
Evaluation of view out: access to view
Evaluation of view out: content of the view
Evaluation of view out: clarity of the view
LIFE-CYCLE ASSESSMENT
LCA for electric lighting installation
LCA for daylighting / shading / facade systems
LCA for integrated lighting solution
Built-in LCA methodology
Import / export links to LCA software
LCA database included
Links to external LCA database

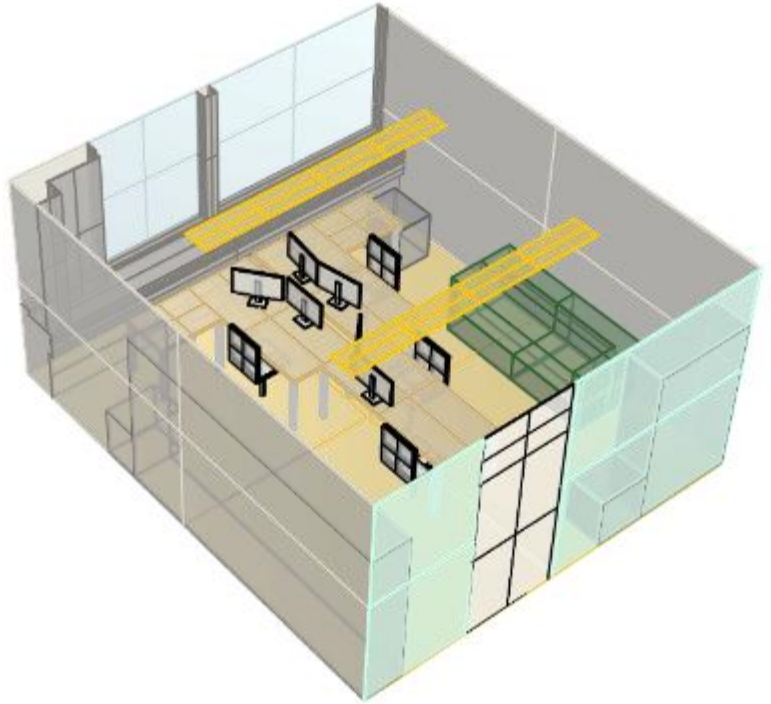
Reference Rooms

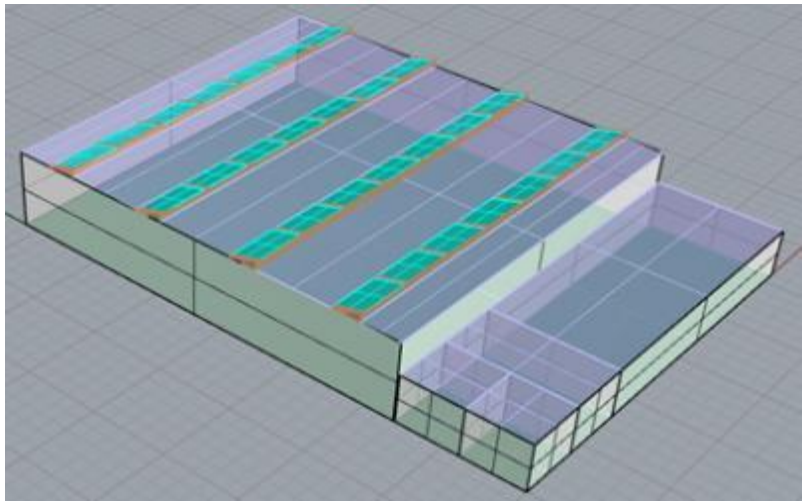
1. Reference Office

   Group office building at University of Innsbruck, Living Lab 518

2. Reference Hall

   Reference factory hall according to Technical Report CEN/TR 15193-2

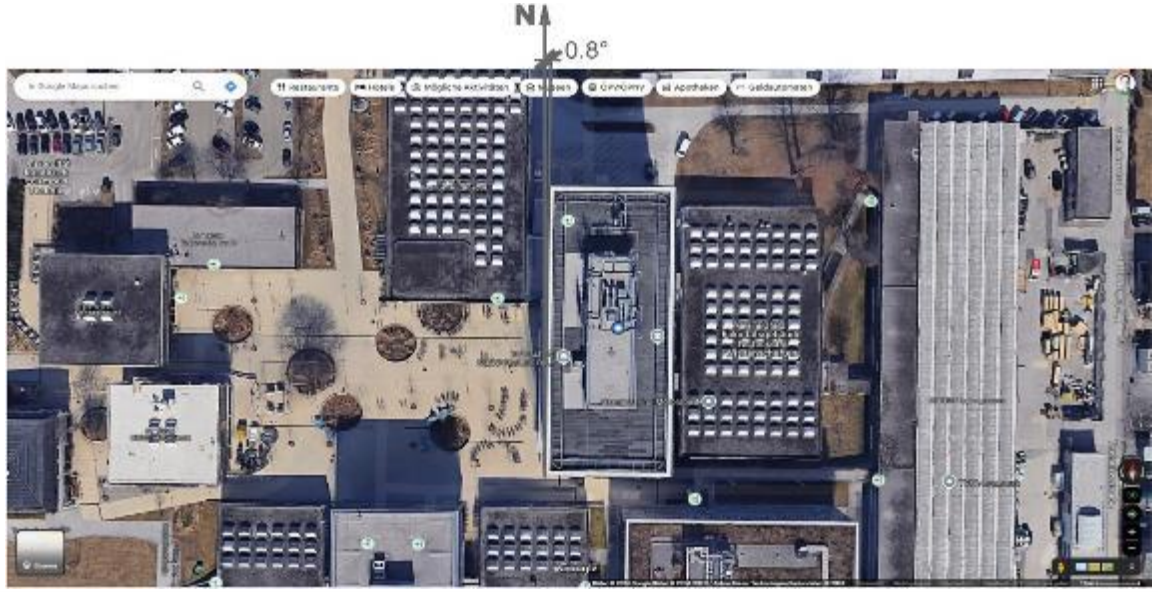


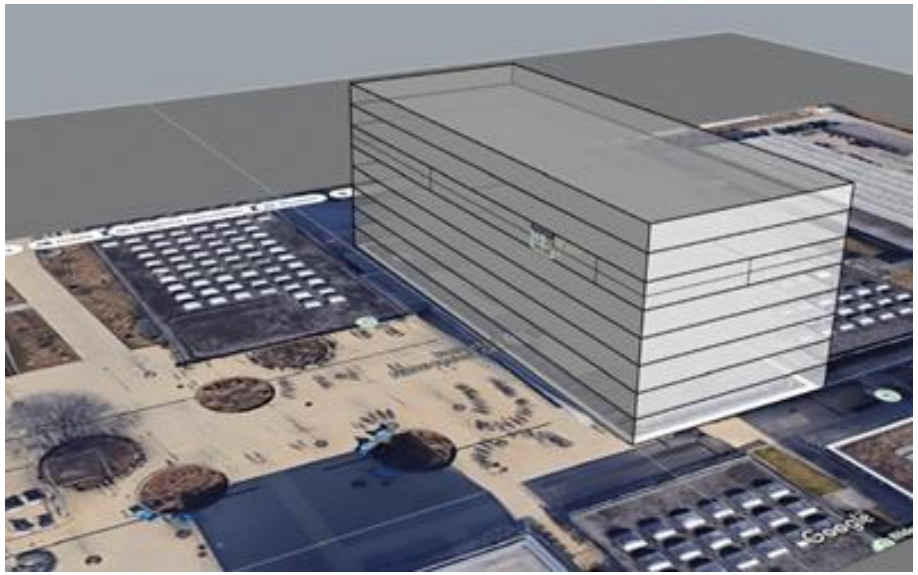


Reference Office

Building

- Location: Innsbruck, Austria, 47° N, 11° E
  https://maps.app.goo.gl/tTSLDgKHeKrPP16Y7
- Climate: AUT_Innsbruck.111200_IWEC.epw

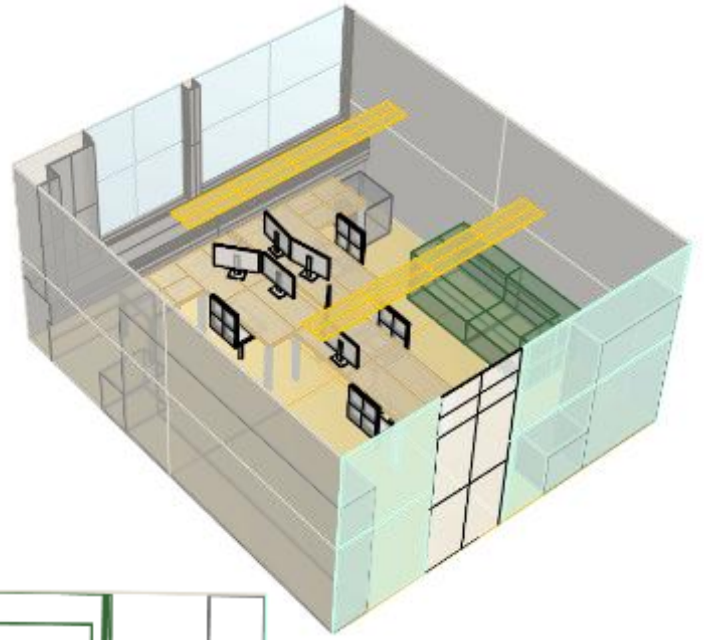




Reference Office

Geometry

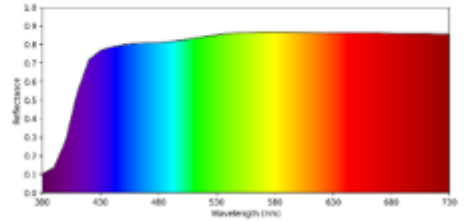
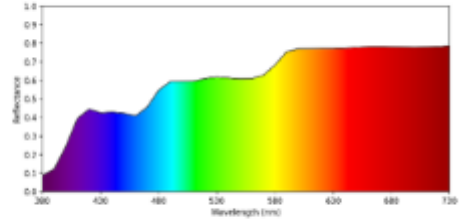
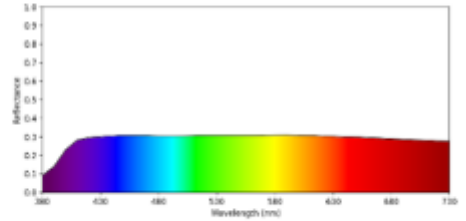
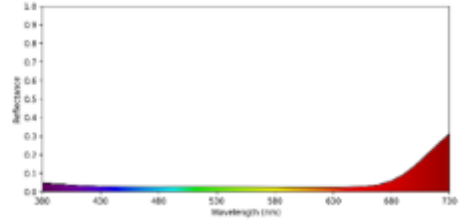
- 5.55 m x 4.86 m x 2.69 m sidelit office with two windows (2.34 m x 1.66 m and 1.39 m x 1.66 m)
- 3D model (3dm file)
- Facade orientation: West (270.8°)
- Shading lines: far and near shading specified as elevation angle per azimuth angle (txt file)



Reference Office

Materials

- most opaque materials measured with a handheld spectrometer (Gretag MacBeth Spectrolino) in the Living Lab office
- spectral data for “Façade” and “Exterior ground” selected from the Spectral Materials Database[1]
- transparent materials generated using LBNL’s Optics[2] software based on spectral data from the IGDB[3]

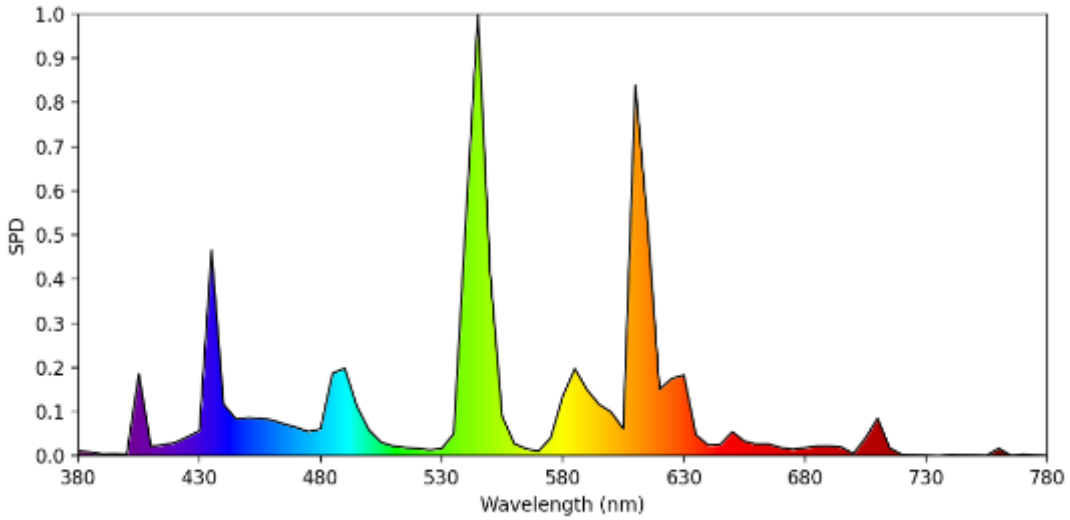
Door (door)	White	85.66%	85.57%	81.73%	T70_office_door.csv 
Desks (desks)	Wood	65.58%	64.98%	53.85%	T70_office_desk.csv 
Desk legs (desk_legs)	Aluminum	30.78%	30.78%	30.62%	T70_office_desk_legs.csv 
Chairs (chairs)	Black	2.60%	2.60%	2.67%	T70_office_chairs.csv 

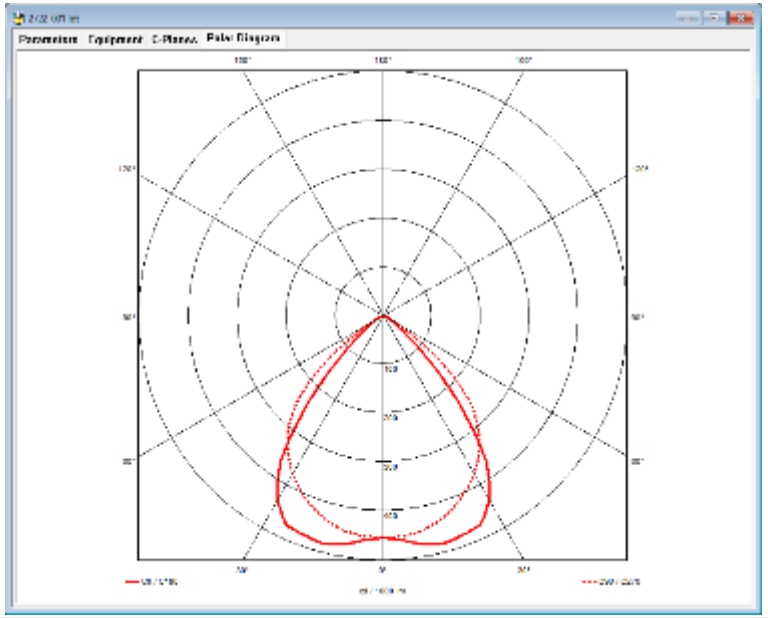
1. https://spectraldb.com/
2. https://windows.lbl.gov/optics-downloads
3. https://windows.lbl.gov/igdb-downloads

Reference Office

Luminaires

- LIDC modeled from datasheet
- spectral data for 840 fluorescent lamp

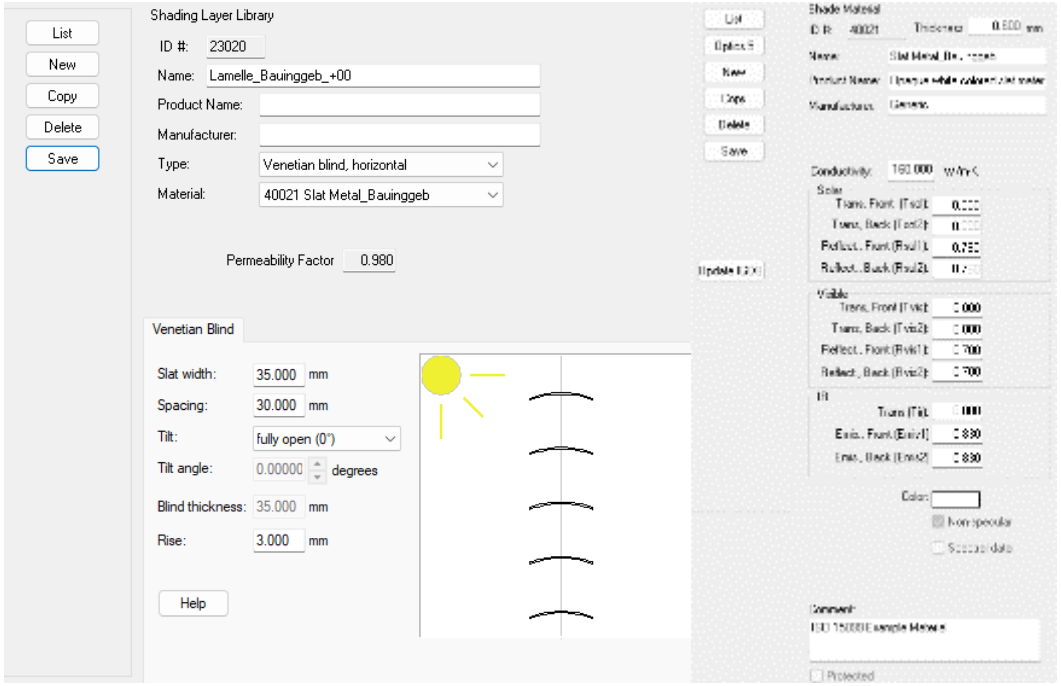


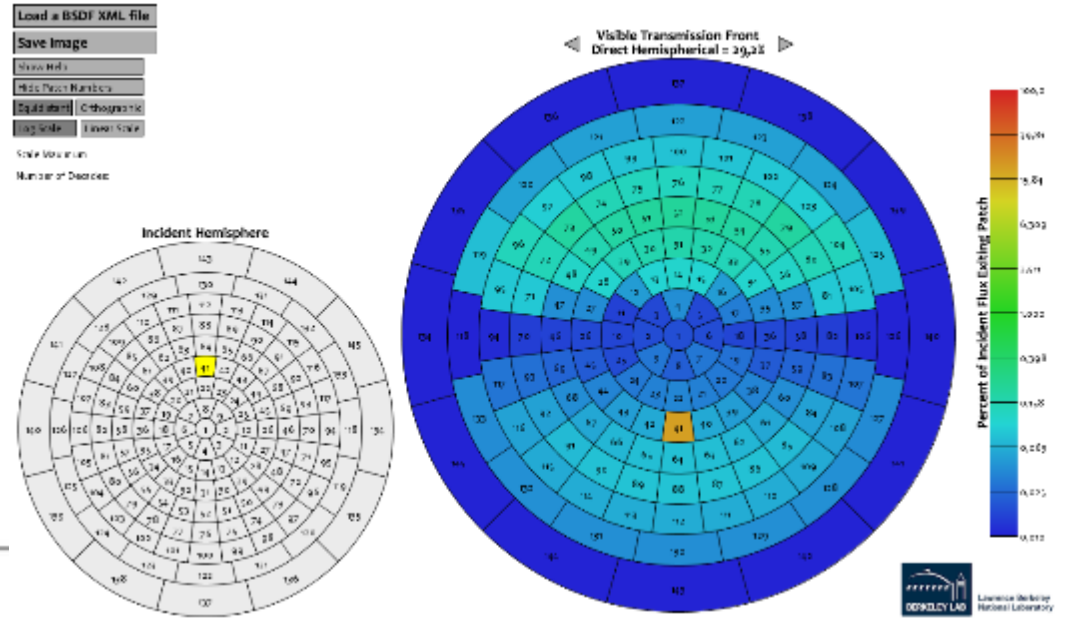


Reference Office

Window system

- Closed cavity windows (internal triple pane thermal insulation glazing, venetian blinds in the cavity; external single-pane glass)
- Modeled in WINDOW
- Assumed spectrally neutral ($\rho_v = 0.7$)
- Data provided for glazing only and combination in 5° tilt angle steps
  - 2D-SHGC (angular data: SHGC, τ and α per layer)
  - BSDF (XML)
  - CSV (plain BSDF data)

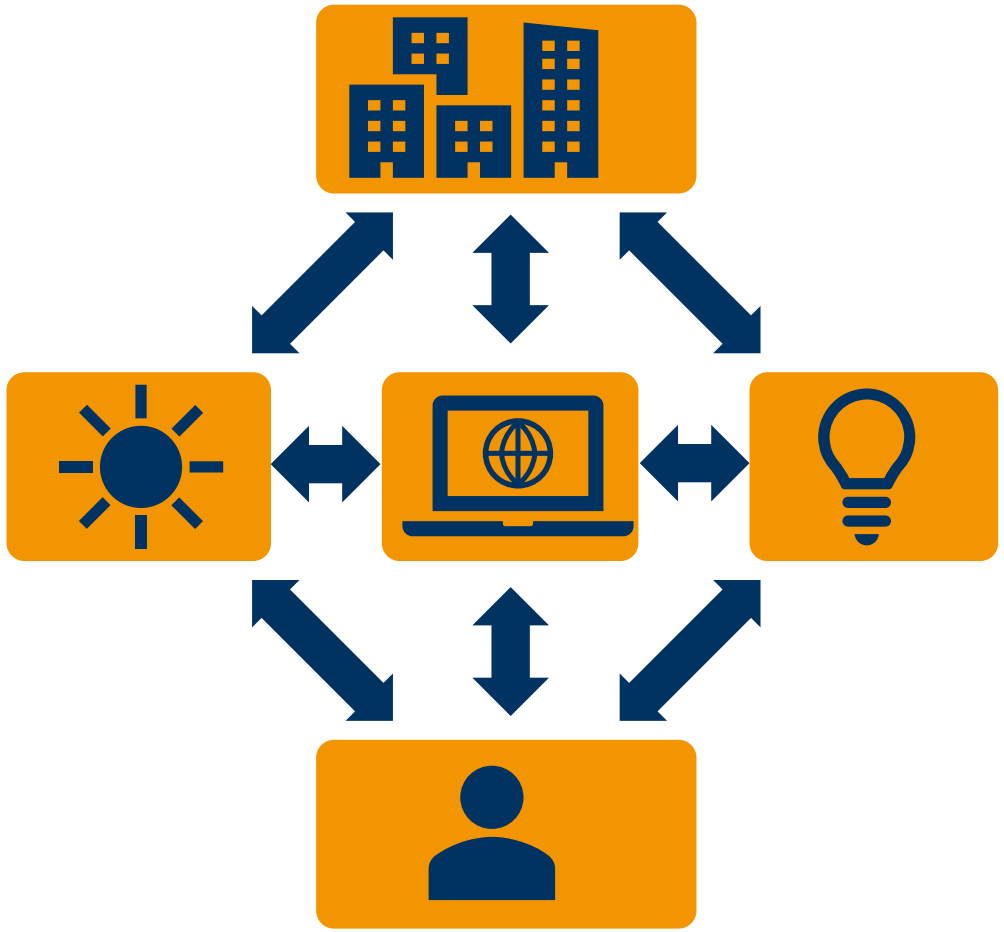




Reference Office

Control

- Shading:
  if global vertical irradiance > 120 W/m2, blinds are fully lowered in almost closed position (75° tilt angle; both windows simultaneously)
- Electric lighting:
  daylight dependent control (combined PIR occupancy and look-down brightness sensor centered on ceiling), light is dimmed to an average of 500 lux at the two workplaces as well as the side table (third desk), maintenance factor 0.8
- Manual intervention:
  possible via a button next to the door for both the shading system (up/down and tilting) as well as the luminaires (on/off, dimming), but not included in the specification of the reference office setup



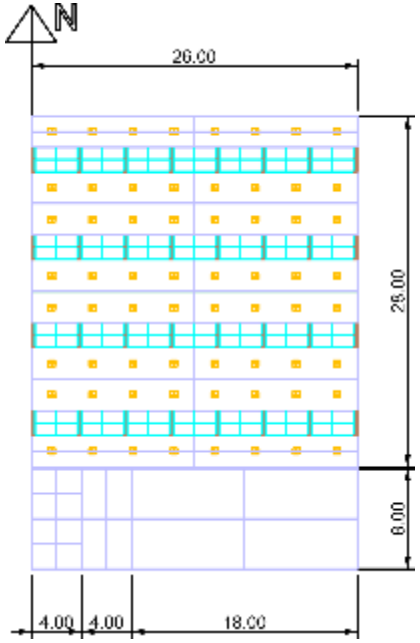
Reference Factory Hall

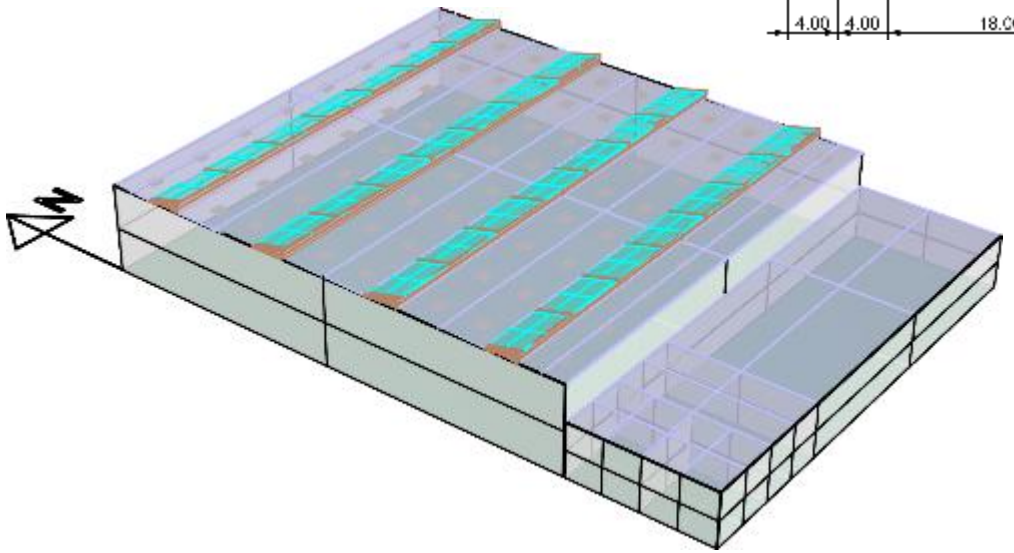
Building

- Location: Stuttgart, Germany
- Climate: DEU_Stuttgart.107380_IWEC.epw

Geometry

- 28 m x 28 m x 5 m
- 3D model (3dm file)
- Rooflight orientation: North
- No external shading

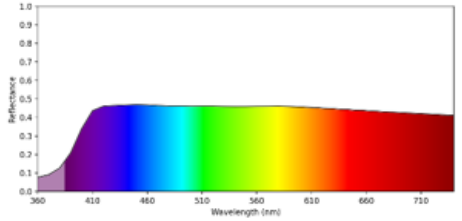
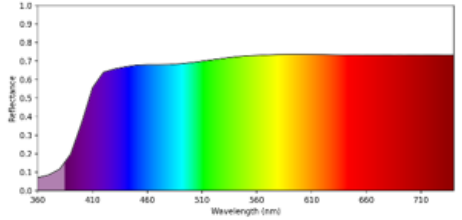
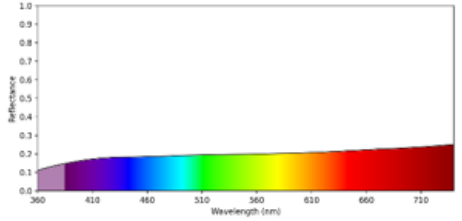




Reference Factory Hall

Materials

- Color neutral opaque materials matching the specified reflectances selected from the Spectral Materials Database[1]
- transparent materials generated using LBNL's Optics[2] software based on spectral data from the IGDB[3]

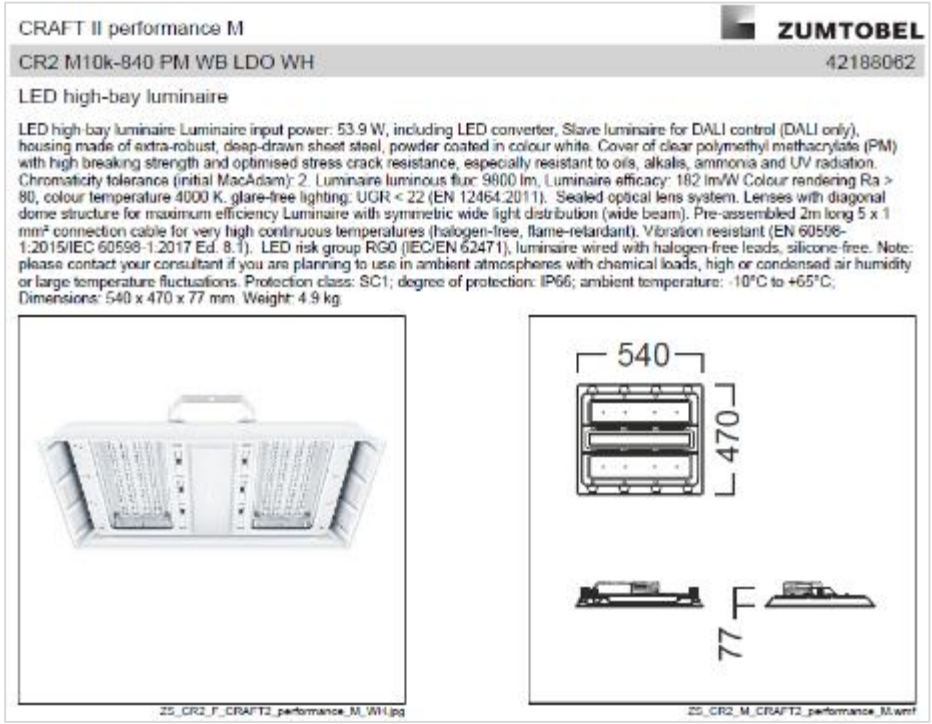
Geometry (layer name)	Color	V(λ) reflectance	M(λ) reflectance	Spectral data
Walls (factory walls)	Neutral, 50%	45.83%	46.30%	00552_spectral.csv / 00552_spectral_sci.csv 
Ceiling (factory ceiling)	Neutral, 70%	72.33%	69.03%	00995_spectral.csv / 00995_spectral_sci.csv 
Floor (factory floor)	Neutral, 20%	20.06%	19.10%	00002_spectral.csv / 00002_spectral_sci.csv 

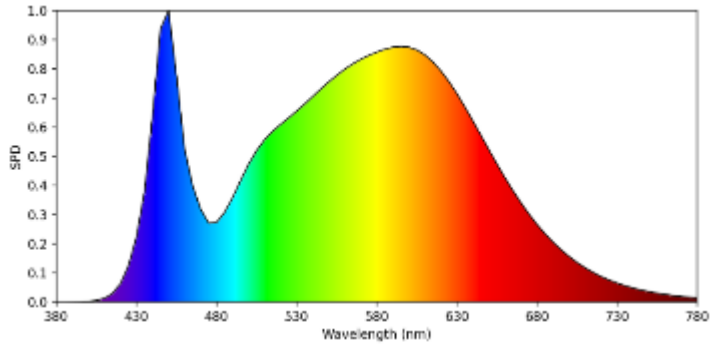
1. https://spectraldb.com/
2. https://windows.lbl.gov/optics-downloads
3. https://windows.lbl.gov/igdb-downloads

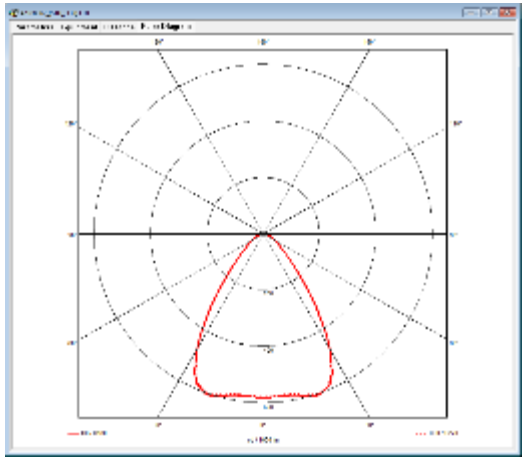
Reference Factory Hall

Luminaires

- CEN/TR 15193-2 specifies daylight dependent dimmable LED luminaire
- Typical high-bay luminaire selected from online catalogue
- Spectrum of typical LED lamp with 4000 K and Ra 85 (CIE LED lamp 03)



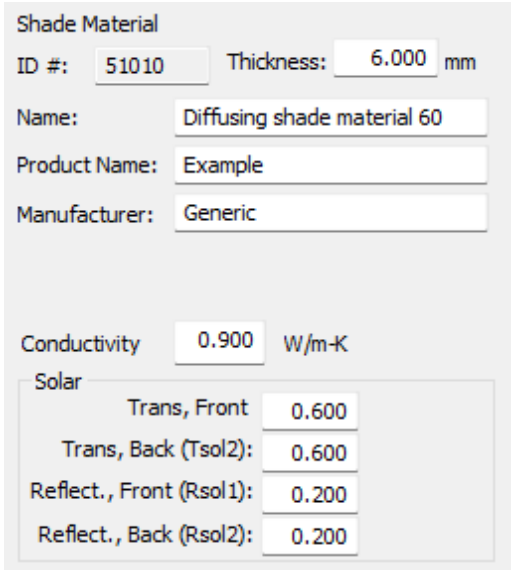


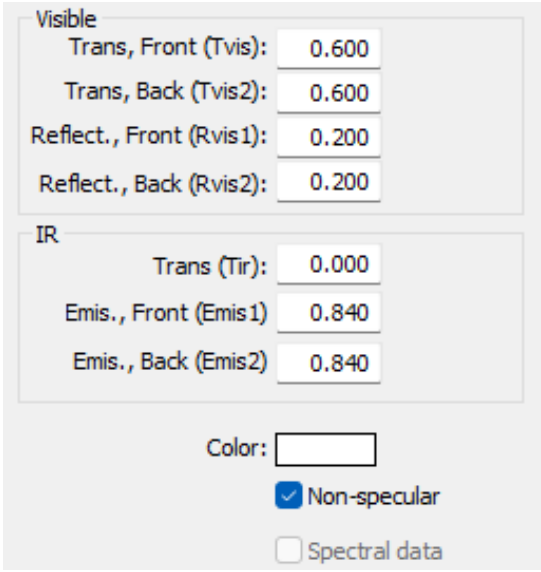


Reference Factory Hall

Rooflight

- Double pane insulation glazing with additional third diffusing pane on the exterior
- Modeled in WINDOW
- diffusing pane adapted from CGDB entry ID 31002 and defined as diffusing material with assumed spectrally neutral behavior
- Provided data:
  - BSDF (XML)
  - CSV (plain BSDF data)

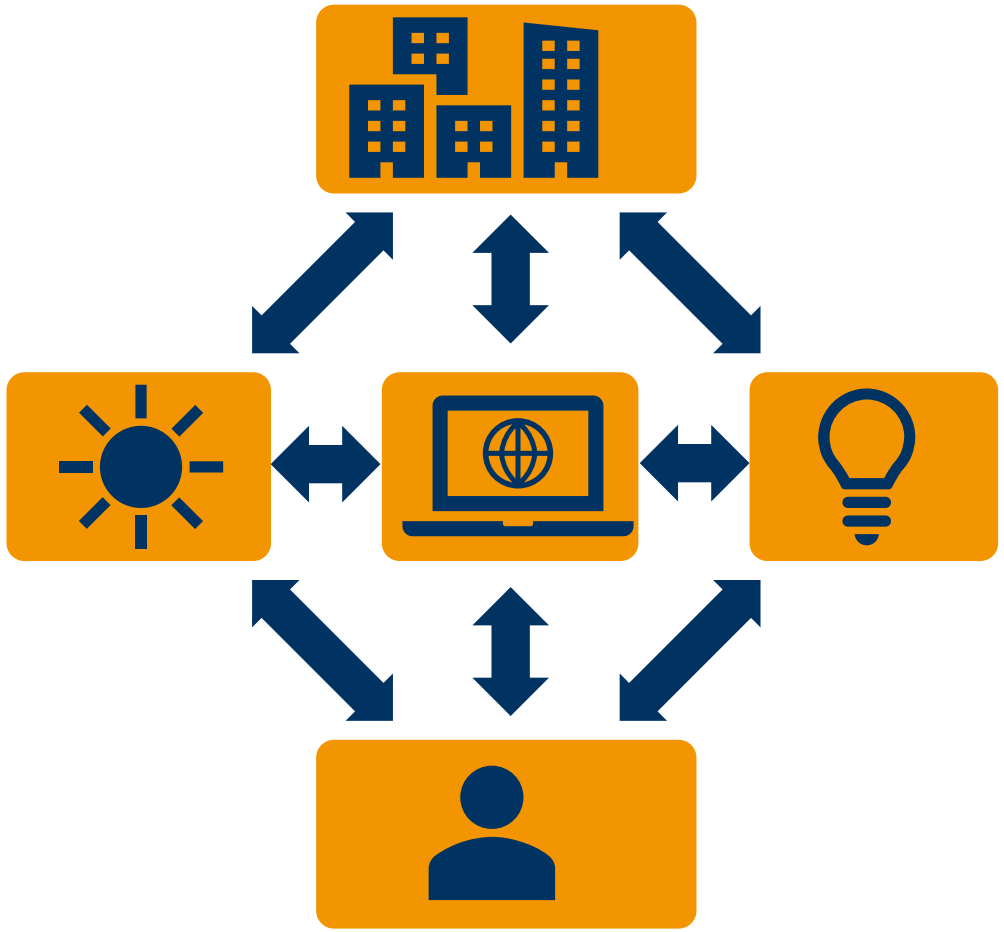




Reference Factory Hall

Control

- Shading:
  none (rooflight has no dynamic parts)
- Electric lighting:
  daylight dependent control (look-down brightness sensor located between rooflight bands), maintained illuminance is 500 lux, maintenance factor 0.8
- Working hours:
  8 am to 5 pm, Monday through Friday, with no shut down for holidays



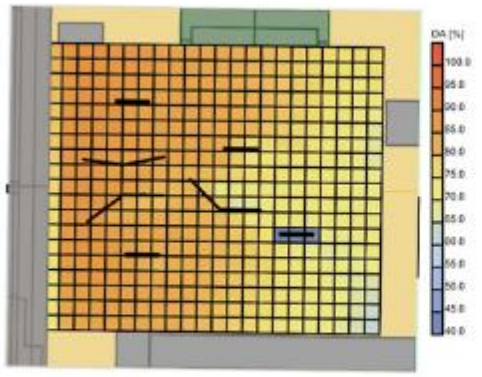
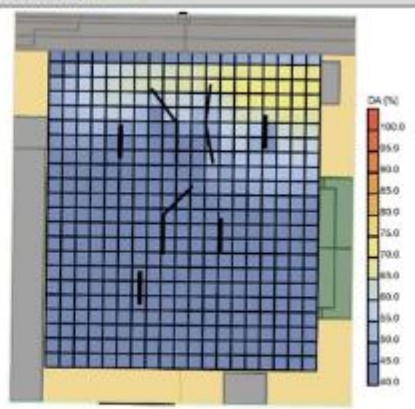
Reporting of Simulation Results

Template for reporting of simulations

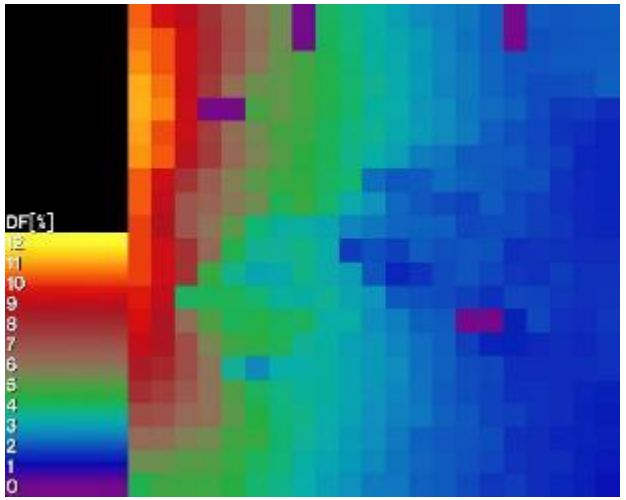
- General
  - Author
  - Software / hardware
  - Comments
- Results
  - Daylight
  - Electric lighting
  - Circadian lighting
  - HVAC electricity / energy use

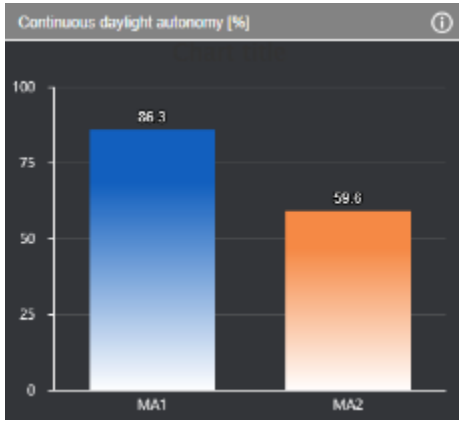
Results for reference case “office”:

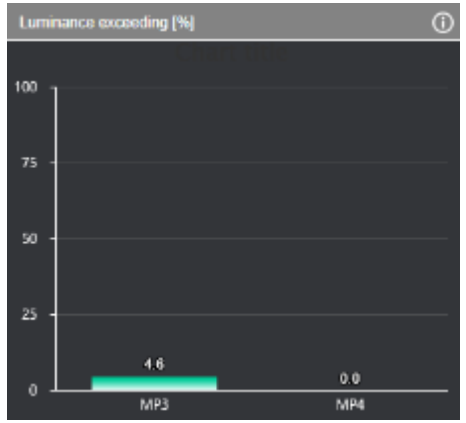
	Metric	Reference case	Context ABCDE
Daylight Factor (CIE overcast sky)	DF min	1.11 %	0.12%
	DF mx	9.99%	8.88%
	DF avg	5.55%	4.44%
	% area with at least 2% DF	33.3%	22.2%
Daylight metrics based on annual results	$sDA_{300,50\%}$	77.7%	33.3%
	$ASE_{1000,250h}$	11.1%	2.22%
	% area with at least 50% $UDI_{100\text{-}3000}$	77.7%	55.5%
	$F_{DGP=0.40,exceed}$ for view 1	4.44%	1.11%
	$F_{DGP=0.40,exceed}$ for view 2	3.33%	2.22%
Circadian lighting	mEDI	222.2 lx	333.3 lx
Electric lighting	Annual electricity use	111.1 kWh / yr	222.2 kWh / yr
			2345 h
			11.1 kWh / yr (air-air heat pump)
			– (no cooling)
			44.4 kWh / yr
			–
			– (no cooling)
			–

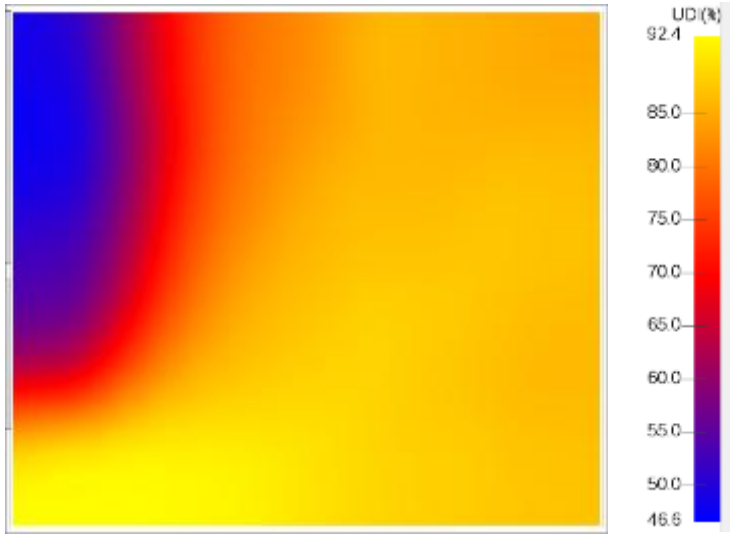
Reference case	Context ABCDE
	
Spatial distribution of Daylight Autonomy (DA [%]) for the reference office (window is on the left side, West)	Spatial distribution of Daylight Autonomy (DA [%]) for the office in context ABCDE (window is on the top, North)

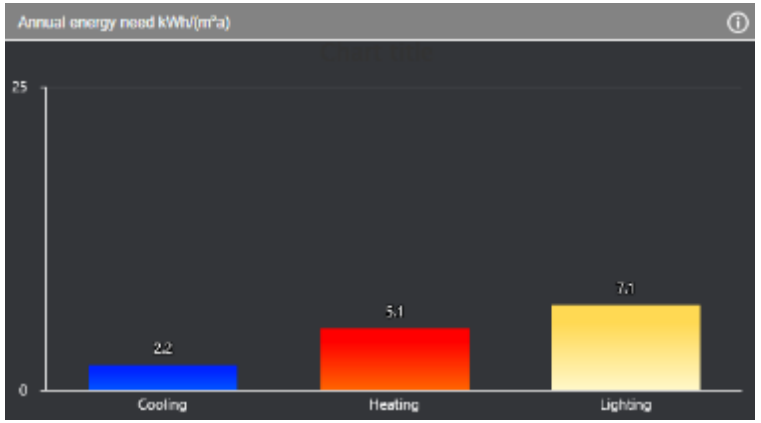
Example Results











Access to reports and reference model dataset

IEA SHC Task 70 / EBC Annex 90 Project Website
https://task70.iea-shc.org/

Task Publications
https://task70.iea-shc.org/publications

Reference model dataset
Geisler-Moroder, D., Maskarenj, M., Ward, G., Wang, T., Lee, E. S., & Altomonte, S. (2026). Reference Models for Spectral Lighting and Daylight Simulations (Original version of dataset uploaded to be referenced by data paper.). Zenodo. https://doi.org/10.5281/zenodo.18836177

Acknowledgements

Funded by

Federal Ministry
Innovation, Mobility
and Infrastructure
Republic of Austria

FFG
Promoting Innovation.

Funding

The research was supported by the **Austrian-China Low Carbon Building and Energy Joint Laboratory** and the project **"CFS4LowCarb" in the TECXPORT Bilateral Cooperation Austria - PRC / MOST 2022 program under project FO999903877** financed by the Federal Ministry of Austria BMIMI managed by the FFG and the **International Energy Agency IEA SHC Task 70/EBC Annex 90 research project (FO999900356)** and by the **National Key R&D Program of China (Grant No. 2023YFE0106700)**, the **National Natural Science Foundation of China (Grant No. 52378096)**, the **China Scholarship Council Program (Project ID: 202506130028)**, the **Hunan Provincial Innovation Foundation for Postgraduate (Project ID: LXBZZ2024023)**.

Support

We thank **all colleagues involved in the international project IEA SHC Task 70 / EBC Annex 90** for their valuable feedback on the development of the reference rooms and for their cooperation in evaluating countless software solutions from around the world.

Special thanks to **Greg Ward and Taoning Wang** for providing the Radiance model. Further, we thank **Alstan Jakubiec** for generously providing spectral reflectance data in the Spectral Materials Database (https://www.spectraldb.com/).

Thank you!

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