IEA SHC Task 61 / EBC Annex 77

Integrated Solutions for Daylight and Electric Lighting

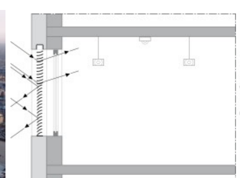
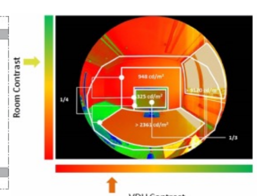
From component to user centered system efficiency

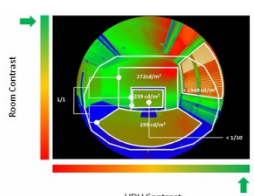
Task Duration: 1/2018 – 6/2021

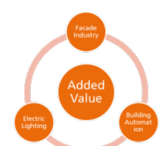
What we have learned ? What we are still learning…

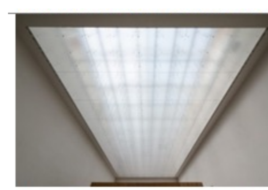
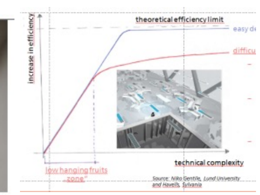
National Day Seminar, Netherlands, 15th June 2021

Dr. Jan de Boer, Fraunhofer Institute of Building Physics, Stuttgart, Germany





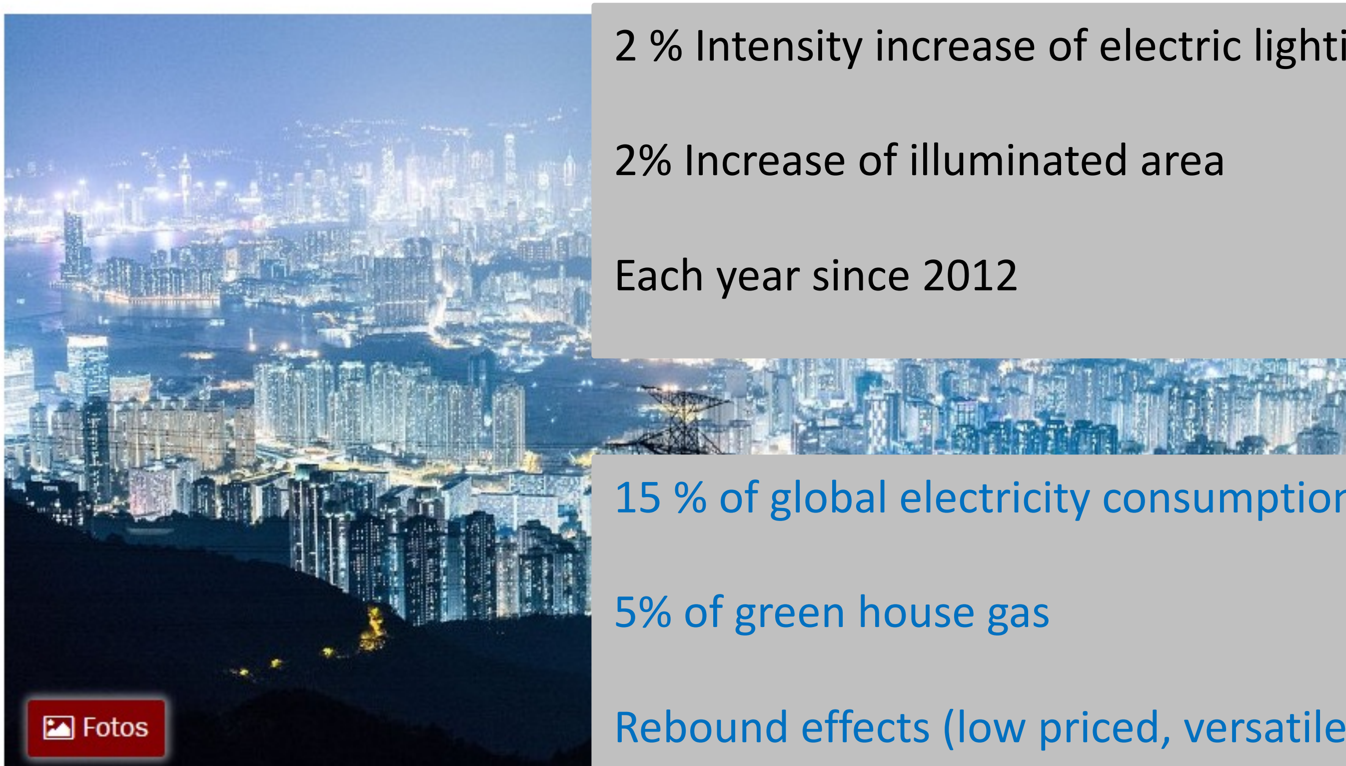
Lichtverschmutzung

Die Welt strahlt. Leider.

„The World is shining. Unfortunatly.“

Eigentlich sollten LED-Leuchten beim Energiesparen helfen. Doch Spareffekte verpuffen, weil auch noch der letzte Fleck ausgeleuchtet wird. Neue Satellitendaten zeigen, wie die Nacht verschwindet.

Von Christoph Seidler



2 % Intensity increase of electric lighting

2% Increase of illuminated area

Each year since 2012

15 % of global electricity consumption

5% of green house gas

Rebound effects (low priced, versatile SSL)

Market Background

- <u>Electric Lighting:</u>
  - High efficient LED Systems, LEDs > 70% of market volume (Europe)
  - Digitalization of light

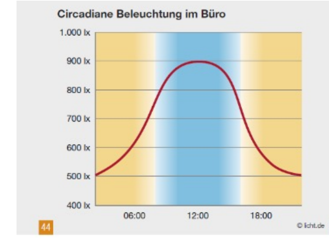
- <u>Facade</u>
  - 1,3 Billion m² of new facades per year (equivalent of the area of the city of London)
  - How this is done has huge impact on daylight supply

- <u>General Trend:</u> From Component to System solutions

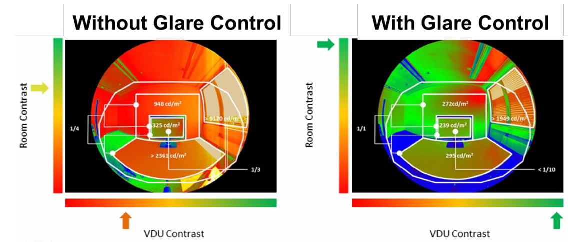
Motivation

Open issues in the integration of day- and electric lighting

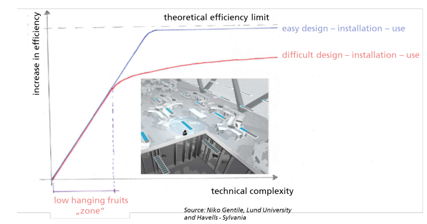
Motivation



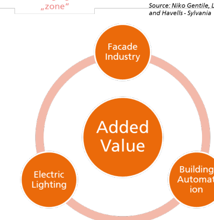
- User Perspective: Change in design and control parameters



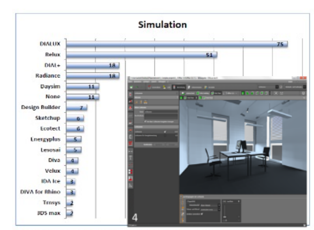
- Facade control is a daylighting problem



- Complexity vs. efficiency in lighting controls



- Combine competencies: Market integration

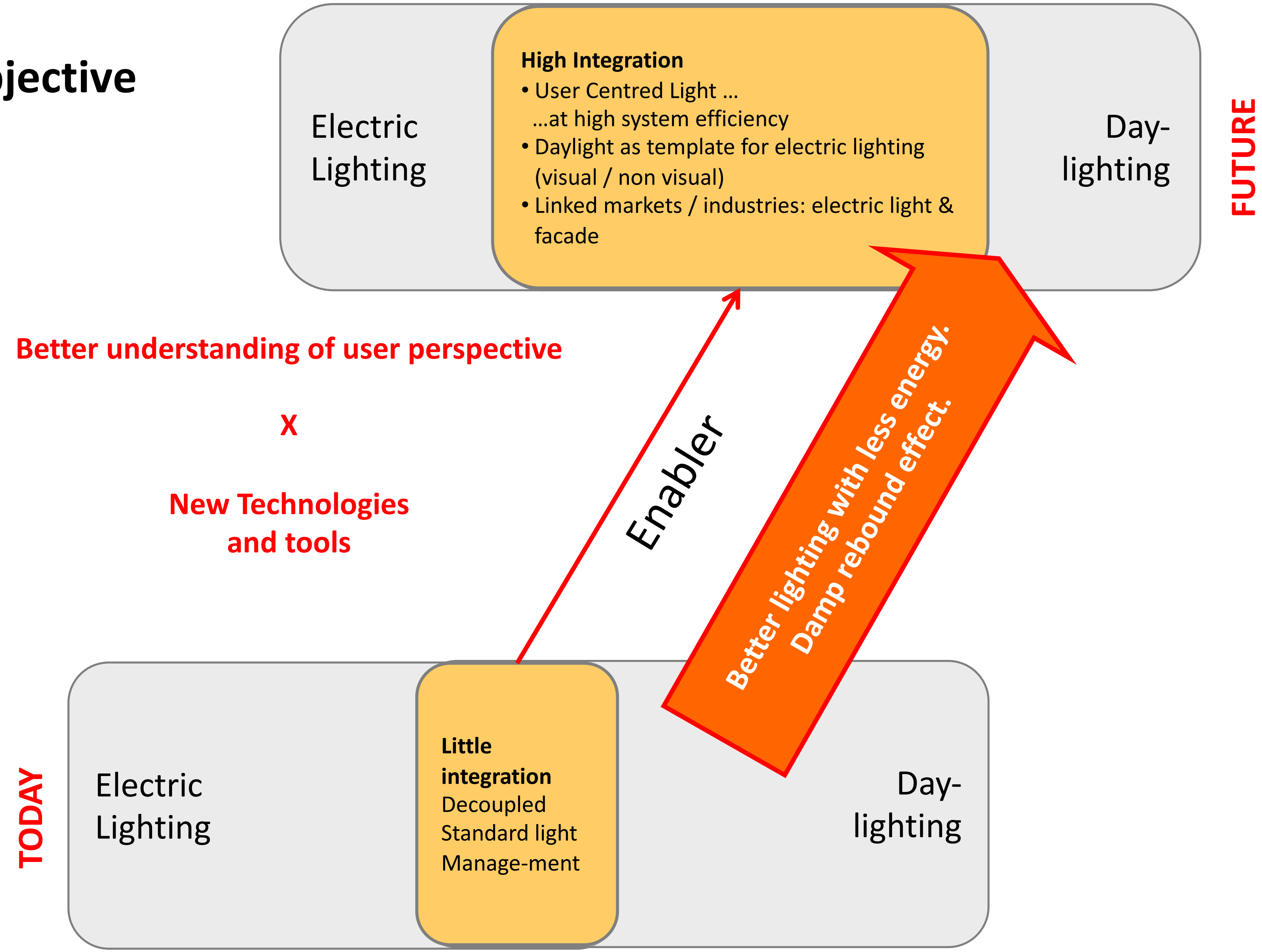


- Codes / Regulations < - > Tools & Methods

Objective of IEA SHC Task 61

Foster the integration of daylight and electric lighting solutions to the benefits of higher user satisfaction and at the same time energy savings

Objective


Electric Lighting
High Integration
• User Centred Light …
…at high system efficiency
• Daylight as template for electric lighting (visual / non visual)
• Linked markets / industries: electric light & facade
Day-lighting
FUTURE
Better understanding of user perspective
X
New Technologies and tools
Enabler
Better lighting with less energy.
Damp rebound effect.
TODAY
Electric Lighting
Little integration
Decoupled
Standard light
Manage-ment
Day-lighting

Task Structure (Duration 1/2018 – 6/2021)

IEA SHC Task 61 / EBC Annex 77

Integrated solutions for daylight and electric lighting

From component to user centered system efficiency

Operating Agent: J. de Boer, Germany

Subtask A

B. Matusiak, Norway

User Perspective, Requirements

Subtask B

M. Fontoynont, Denmark

Integration and optimization of daylight and electric lighting

Subtask C

D. Geisler-Moroder, Austria

Design support for practioners

(Tools, Standards, Guidelines)

Subtask D

N. Gentile, Sweden

W.Osterhaus, Denmark

Lab and field study performance tracking

Joint Working Group

- Evaluation method for integrated lighting solutions
- Virtual reality (VR) based Decision Guide

Who is behind the activity?

About 35 Experts from 14 countries

Research

INFORM DESIGN
KYUSHU UNIVERSITY
DTU Technical University of Denmark
UCL Université catholique de Louvain
AARHUS UNIVERSITY
bbri.be
Universidade de Brasília
Bartenbach
BERKELEY LAB
Fraunhofer ISE
LUND UNIVERSITY
POLITECNICO DI TORINO
Haute école d'ingénierie et d'architecture Fribourg
Hochschule für Technik und Architektur Freiburg
DANISH BUILDING RESEARCH INSTITUTE
AALBORG UNIVERSITY COPENHAGEN
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
Fraunhofer IBP
SUTD SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN
NTNU
QUT Queensland University of Technology

Industry

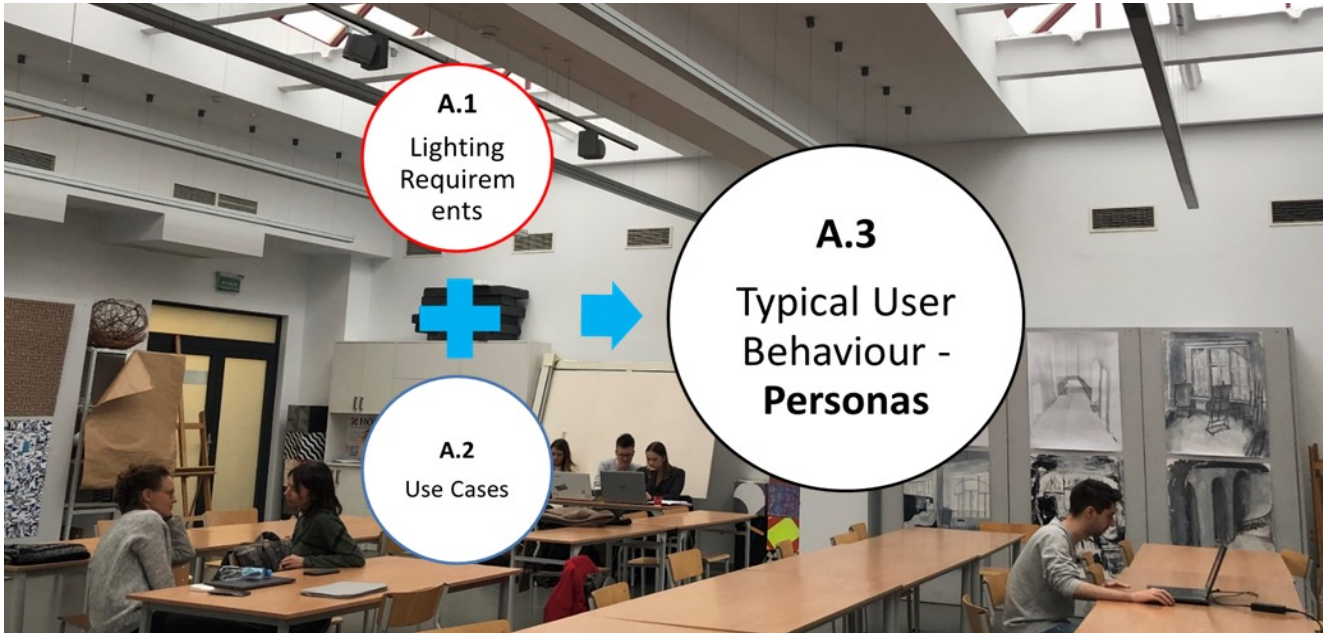
HELLA
VELUX
PHILIPS Lighting
LIGHTCARE The second best light on earth
DCL
DIAL
MicroShade
AW
ZUMTOBEL
Norconsult

Subtask A

User Perspective, Requirements

Coordination: Barbara Matusiak, NTNU, Norway

Consolidation of available knowledge on user-, activity- and time-depending visual and non-visual *requirements* including cultural and climatic dependencies. Set up *use cases* in specific applications, reflecting typical temporal changes in the usage of these interior spaces. Aggregation in so called *personas* as representations of the behaviour of a hypothesized group of users in the defined applications.



User perspective and requirements

More than 100 articles reviewed

28 criteria analysed

Report Available

Contents

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Van de Perre, L., Hanselaer, P., Scheir, GH., Smet, K., Ryckaert, WR. (2016) Contrast metrics evaluation. In *Proceedings of CIE 2016 "Lighting Quality and Energy Efficiency "*. Melbourne, Australia: CIE, 70-78

Stokkerman,s M., Vogels, I., de Kort, Y. and Heynderic,. I. (2017) Relation between the perceived atmosphere of a lit environment and perceptual attributes of light. *Lighting Research and Technology*; 0: 1–15

Van de Perre, L., Ryckaert, W.R., Dujardin, M., Smet, K.A.G. (2018) Contrasts and Brightness Perception of Illumination Patterns in Physically-based Rendered Scenes. *CIE Midterm Meetings and Conference on Smarter Lighting for Better Life*.

3.5 Flicker

Flicker may be divided into two types. One that is visual, i.e. it is possible to detect the flickering light with the eyes, and the other which could be named subliminal i.e. the flickering light is not consciously detected by the human, but the brain is registering the flicker.

Flickering lights can be uncomfortable to look at and can induce seizures in observers with photosensitive epilepsy. Subliminal flicker may cause headache, and impaired cognitive performance. Temporal modulation of lighting at frequencies higher than the critical fusion frequency can affect human efficiency in diverse ways that are not understood.

Measures for flicker are needed and methods have been proposed. Today it is important to have measures since pulse width modulation for dimming the light output of LEDs has become common. These artefacts need to be avoided or at least reduced to a minimum in order to obtain high user acceptance.

3.5.1 References

Anstis, S. & Rogers, B. (2012) Binocular fusion of luminance, colour, motion and flicker – Two eyes are worse. than one. *Vision Research* 53, 47–53

Bodington, D., Bierman, A. & Narendran, N. (2016) A flicker perception metric. *Lighting Research and Technology*. 48, 624–641

Boyce, PR., & Wilkins, AJ. (2018) Visual discomfort indoors. *Lighting Research and Technology*. 50: 98–114

Herrmann, CS. (2001) Human EEG responses to 1–100 Hz flicker: resonance phenomena in visual cortex and their potential correlation to cognitive phenomena. *Exp Brain Res*. 137: 346–353

Jaén, EM., Colombo, EM. & Kirschbaum, CF. (2011) A simple visual task to assess flicker effects on visual performance. *Lighting Research and Technology* 43: 457–471

Knez, I. (2014) Affective and cognitive reactions to subliminal flicker from fluorescent lighting. *Consciousness and Cognition* 26, 97–104

Liu, M-x., Yan, Y., Xue, Q. & Gong, L. (2015) The research and analysis of factors affecting Critical Flicker Frequency. *Procedia Manufacturing*, 3 4279 – 4286

Polin, D., Klir, S., Wagner, M. & Khanh, TQ. (2017) Reducing the stroboscopic effects of LED luminaires with pulse width modulation control. *Lighting Research and Technology*, 49: 370–380

Wilkins, A., Veitch, J. & Lehman, B. (2010) LED Lighting Flicker and Potential Health Concerns: IEEE Standard PAR1789 Update. *IEEE Energy Convers Congr Expo* 1, 171-178

Yoshimoto, S., Garcia, J., Jiang, F., Wikins, AJ, Takeuchi, T. & Webster, M. (2017) Visual discomfort and flicker. *Vision Research* 138, 18–2

3.6 Spatial frequencies

In the spatial domain, one identified source of visual discomfort is when images have Fourier amplitude spectra that deviate from the natural (1/frequency, 1/f) statistical characteristics of natural scenes, especially if they contain excess energy at the medium frequencies at which the visual system is most sensitive.

Deviation from the statistics of natural images could cause discomfort because the visual system is optimized to encode images with particular statistics typical of natural scenes.

Psychological and physiological benefits of viewing nature have been extensively studied for some time. More recently it has been suggested that some of these positive effects can be explained by nature's fractal properties.

Research suggests that the responses to statistical and exact fractals differ and that the natural form of the fractal is important for inducing alpha responses, and indicator of a wakefully relaxed state and internalized attention.

3.6.1 References

O'Hare, L. & Hibbard, PB. (2011) Spatial frequency and visual discomfort. *Vision Research* 51, 1767–1777

Hägerhäll, CM., Laike, T. Küller, M, Marcheschi, E., Boydston, C. & Taylor, RP. (2015) Human physiological benefits of viewing nature: EEG responses to exact and statistical fractal patterns. *Nonlinear Dynamics, Psychology and Life Sciences*, 19, 1-12

Fernandez, D. & Wilkins, AJ. (2008) Uncomfortable images in art and nature. *Perception*, 37, 1098-1113

Wilkins, AJ. (2016) A physiological basis for visual discomfort: Application in lighting design. *Lighting Research and Technology* 48, 44–54

Hägerhäll, CM., Laike, T., Taylor, RP., Küller, M., Küller, R. & Martin, TP. (2008) Investigations of human EEG response to viewing fractal patterns. *Perception*, 37, 1488 – 1494

3.7 Temporal changes

Studies on load shedding have shown that rapid changes in illuminance (of the order of 10-100 lx/s) suggest that illuminance can decline by up to 20% without being detected. With slower rates of change (1 lx/s or less), greater reductions in illuminance may remain undetected, and acceptable.

In a study where the direct component of a direct-indirect luminaire was reduced by 2% of full output per minute, to a minimum 20% output, the effects were generally negative (a small negative effect on comfort and arousal). There was no effect on environmental satisfaction, or on any of the many task performance outcomes (typing, memory, creativity, anagram solving, vigilance).

Participants with personal control exposed to ramps were not found to be less negatively affected by the ramps than those without personal control.

Temporal changes of daylight in the exterior during a day can be slow or rapid. They are associated with intensity, spectral composition and light colour occurrence. These changes can be observed and are welcome by occupants of interiors. People have a good ability to adapt to intensity and colour variations of natural light. One of the important aspects of a healthy indoor environment is access to daylight and its daily changes. Generally, more blue and brighter light appears the first part of the day while relatively more red light with a low portion of short-wavelength light is in the last two hours before sunset.

3.7.1 References

Newsham, G. R., Donnelli, C., Mancini, S., Marchand, R. G., Lei, W., Charles, K. E. & Veitch, J. A. (2006) The Effect of Ramps in Temperature and Electic Light Level on Office Occupants: A Literature Review and a Laboratory Experiment. *Proceedings of the 2006 ACEEE Summer Study on Energy Efficiency in Buildings*, Pacific Grove, California, pp. 4-252 to 4-264.

Newsham, G. R.; Mancini, S.; Veitch, J. A.; Marchand, R. G.; Lei, W.; Charles, K. E.; Arsenault, C. D. (2009) Control strategies for lighting and ventilation in offices: effects on energy and occupants. *Intelligent Buildings International* 1: 2, 101-121 https://doi.org/10.3763/inbi.2009.0004

S Chraibi, P Creemers, C Rosenkötter, EJ van Loenen, MBC Aries, ALP Rosemann. (2018) Dimming strategies for open office lighting: User experience and acceptance. *Lighting Research and Technology* online first: https://doi-org.zorac.aub.aau.dk/10.1177%2F1477153518772154

Y Akashia, J Nechesb. (2005) Potential recommendations for illuminance reductions by load-shedding. *Lighting Research and Technology* 37:2, 133 -153

User perspective and requirements

	Daylight		Electric light	
Parameter	**Measure**	**Standard value**	**Measure**	**Standard value**
Workplace illuminance General	Target illuminance of daylight provision from windows	≥ 300 lux on the working place level ≥ 50% of the yearly daylight hours ≥ 50% of the space area	Mean E_h on the desk	Together with daylight ≥ 500 lux
	Spaces with skylights	as for windows but ≥ 95% of the space area		
Workplace illuminance Visual demanding	daylight provision from windows	≥ 750 lux on the desk ≥ 50% of the yearly daylight hours	Mean E_h on the desk	1000 lux
Workplace illuminance homogeneity	Minimum Target illuminance of Daylight provision from windows	≥ 100 lux on the working level in room ≥ 50% of the yearly daylight hours ≥ 95% of the space area	Uniformity U_o (E_{min}:E_{mean}) on the desk	≥ 0.6
Workplace illuminance homogeneity Visual demanding	Minimum Target illuminance of Daylight provision from windows	≥ 200 lux on the working level in room ≥ 50% of the yearly daylight hours ≥ 95% of the space area	Uniformity U_o (E_{min}:E_{mean}) on the desk	≥ 0.7
Movement area illuminance	No measure	*Low daylight illuminance is accepted*	Mean E_h	200 lux
Movement area illuminance homogeneity	No measure	*Low daylight illuminance homogeneity is accepted*	U_o (E_{min}:E_{mean})	0.4

Table 1. Application-related requirements for office work, based on the literature review, standards EN-17037 and EN-12464, and the requirements specification according to the EU H2020 research project “Repro-light”.

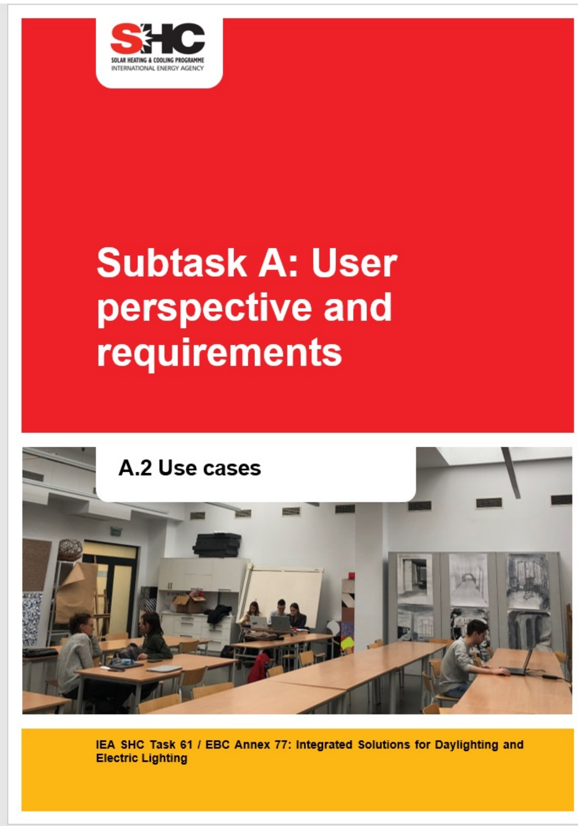
Colour of light in general	No measure	*Natural variation of colour of daylight is appreciated*	CCT (K)	3000 – 5000
Colour of light Wards	No measure	*blue and green tint of window glass should be avoided*	CCT (K)	4000 ≤ T_{cp} ≤ 5000
Workplace colour rendition	Colour rendering for window glass	hue shift ≤ 30 saturation shift ≤30	CRI (additional R_{12})	≥ 80
Workplace colour rendition Colour quality demanding	Colour rendering for window glass	hue shift ≤ 10 saturation shift ≤ 20	CRI (additional R_{12})	≥ 90
View out to the outside from the workplace	Width of the view	> 14°	-	-
	Length of the view	> 6m	-	-
	Number of view layers (ground, landscape, sky)	Minimum landscape layer is visible	-	-
Glare	Daylight glare probability $DGP_{e<5\%}$	< 0.45 besides 5% of the occupation time	UGR	≤ 19
Luminance in the visual field	Max. luminance of the window surface for workplaces in neighbourhood of window	≤ 4000 cd/m²	Max. luminance at gamma > 60°	≤ 3000 cd/m²
Repeating luminance contrasts	Spatial frequency on the window surface	Avoid strong luminance contrast in the medium frequencies (0,2 – 0,5)	Multishadows from lamps Mean illuminance at surface level	≥ 100 lux
Homogeneity of light-emitting surface			L=(L(90%): L(10%)/$L_{average}$	
Non-visual effects of light (daytime work)		Daylight is recommended wherever possible.	Circadian stimulus [CS]	≥ 0.3* (Practically ≥ 0.4) throughout the day
Non-visual effects of light (shift work)			circadian stimulus [CS]	CS ≥ 0.3 throughout first part of the shift (until about 05:00 am), and then shielding themselves from exposure to circadian-effective light until they are home and in their darkened bedroom for sleep

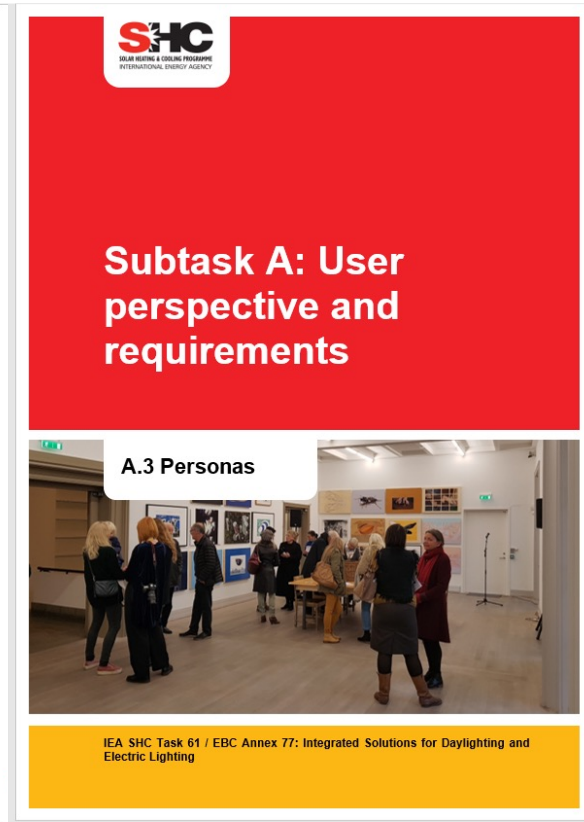
The green background to mark requirements for visual demanding tasks
The blue background to mark requirements with special importance of colour rendering.

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA SHC Subtask A reports

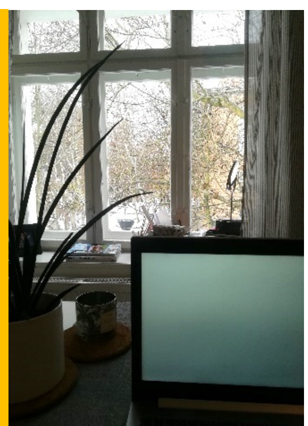
A.1 User requirements
Finished
A.2 Use cases
In progress, to be finished in June 2021
A.3 Personas
In progress, to be finished in Summer





New activity: Visual environ-ment in Home office

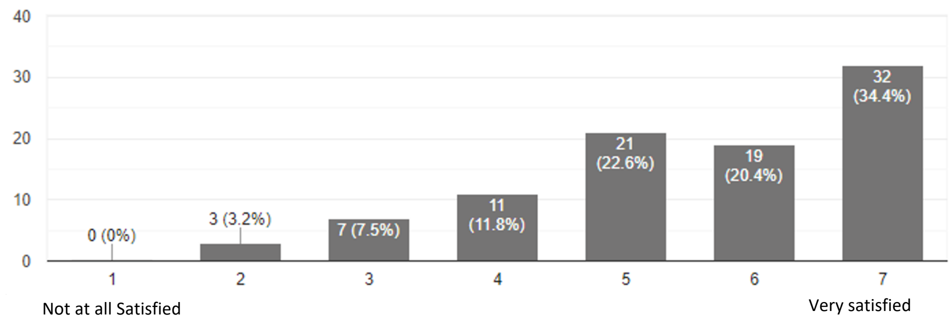
– online survey



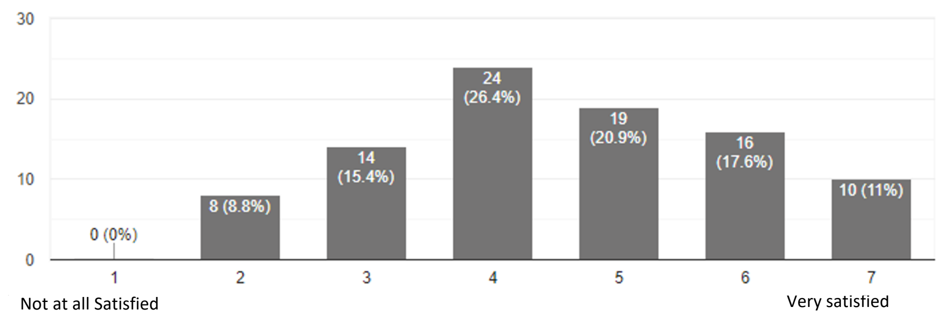
Preliminary Home office results **Brazil: Students**

LIGHTING CONDITION IN THE WHOLE HOME OFFICE ROOM NOW

Satisfaction with daylight?

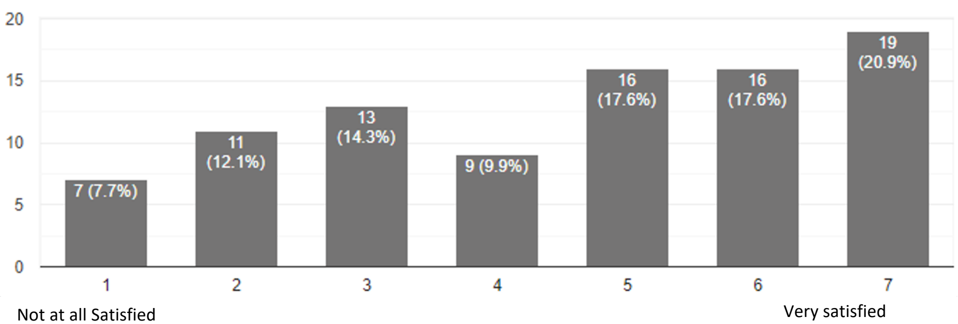


Satisfaction with electrical lighting?

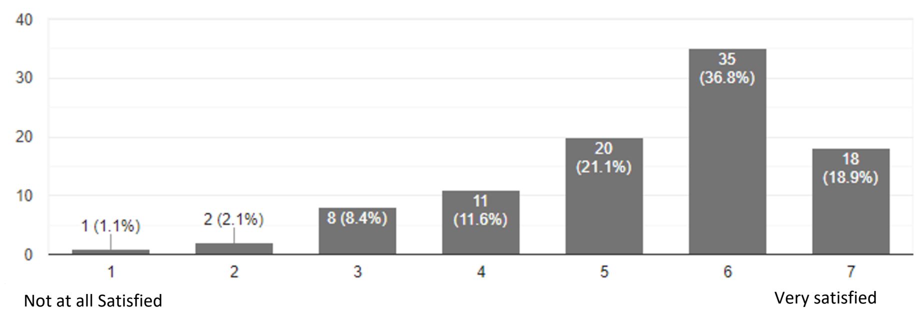


Less satisfaction with both day and electric light, view and general light level when compared with professionals (no exclusive room for home office can explain this?)

Satisfaction with external view from window?



Satisfaction with the general light level in the room?



Subtask B

Integration and optimization of day- and electric lighting

Coordination: Marc Fontoynont, SBI, Denmark

Identify the promising technical solutions to offer optimal control of lighting and daylighting components, with respect to minimum use of lighting electricity, maximum satisfaction of users, most attractive user interface (users and facility managers)

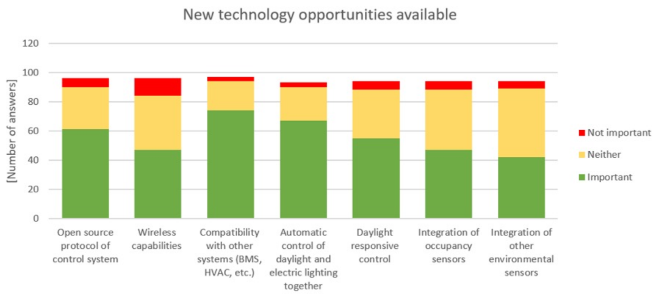
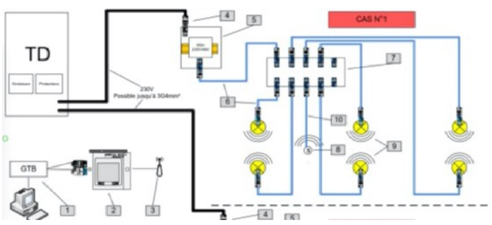


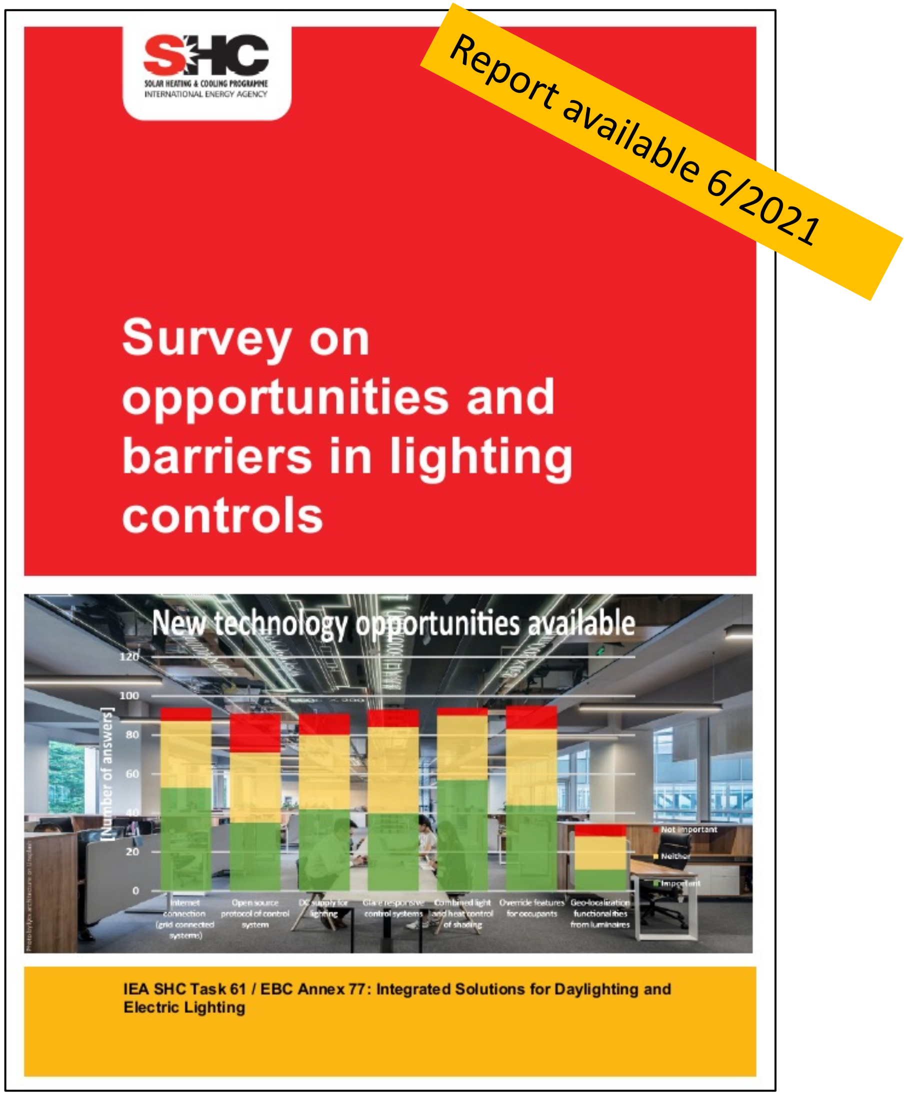
Figure 7: Answers from new technology opportunities available.



Example of DC power architecture for lamps and sensors, with Bluetooth communication (Source: Luxendi).

Source: ZigBeeAlliance

Survey on opportunities and barriers in lighting controls



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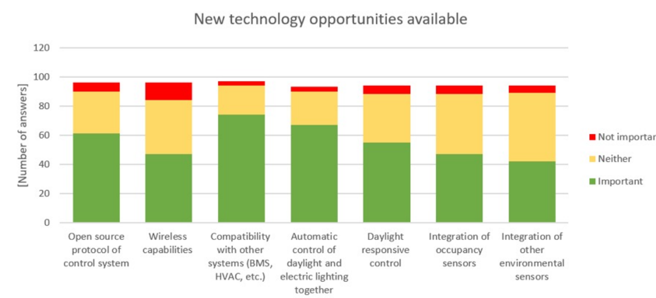


Figure 7: Answers from new technology opportunities available.

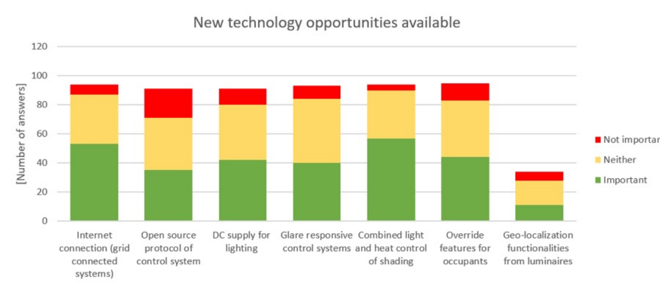
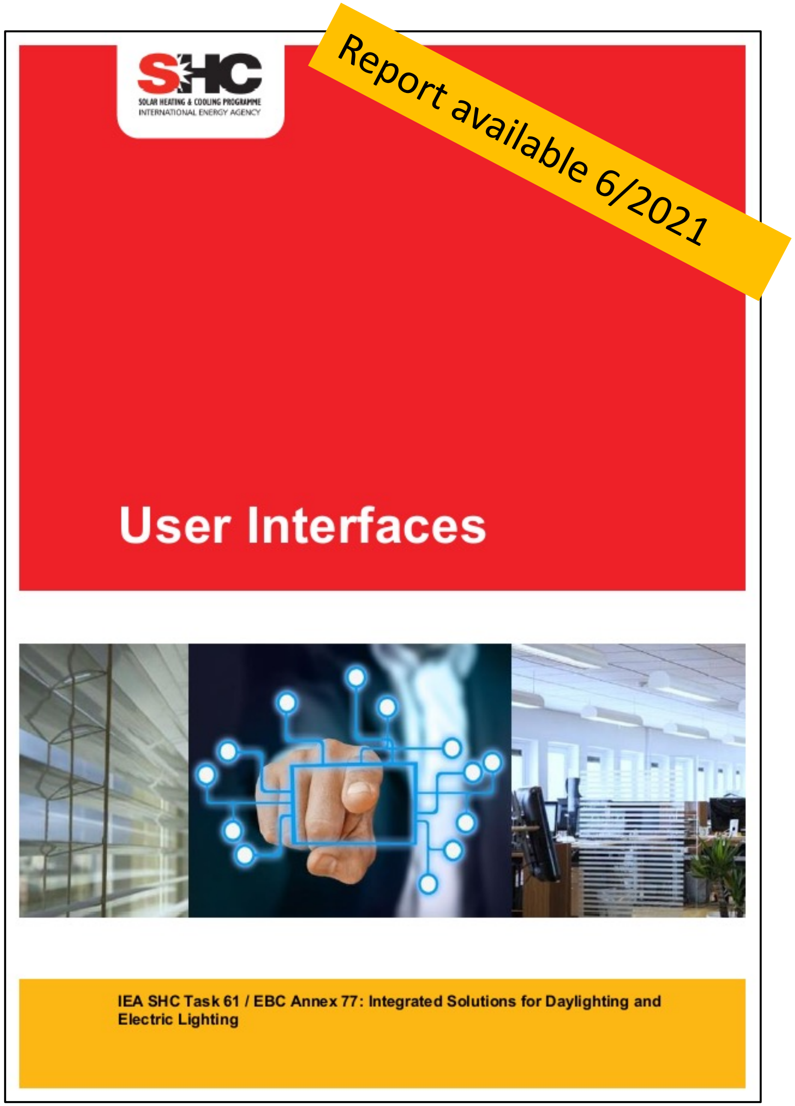


Figure 8: Answers from new technology opportunities available.

Review of lighting and daylight control systems

User Interfaces



- Categories: analog, digital, hybrid
- Components
- Trends
- Link to energy savings
- Combined control of lighting and daylighting
- Consequence on possible occupant satisfaction

Figure 4 Examples of wireless analog controllers that are connected to the combined network. From left: IKEA TRADFRI remote, Phillips HUE On/Off/Scene select remote with dimmer, Phillips Smart Button with 4 programmable buttons.

(Images sources:
https://www.ikea.com/gb/en/p/tradfri-remote-control-30443124/
https://www.conrad.com/p/philips-lighting-hue-remote-control-dimmer-switch-1588619
https://www.greenline.dk/led-paerer/philips-hue/tradlos-philips-hue-kontakt-lysdaemper-med-ramme?gclid=Cj0KCQjw7ZL6BRCmARIsAH6XFDLOAy9_H6KW43ZAqOW6_XtRUrL-0oq-_PWXCZ5qFsJQTHEj0AbhDBsaAsItEALw_wcB)

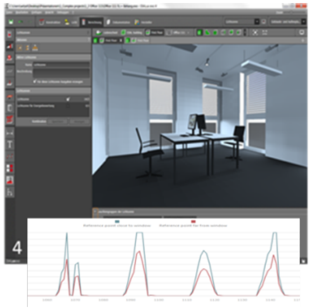
SmartPhone based interfaces by Bubbendorf

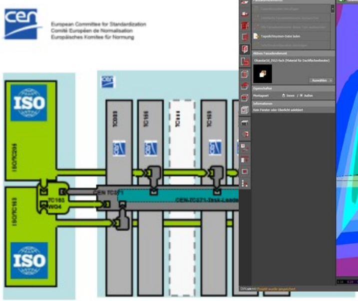
Subtask C

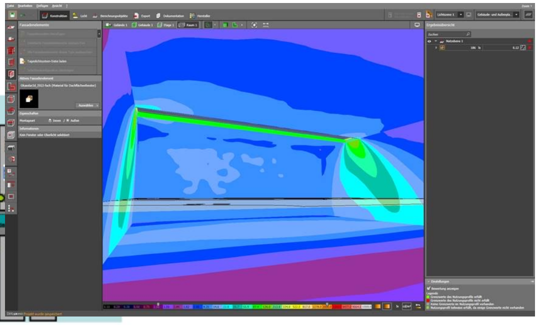
Design Support for practitioners

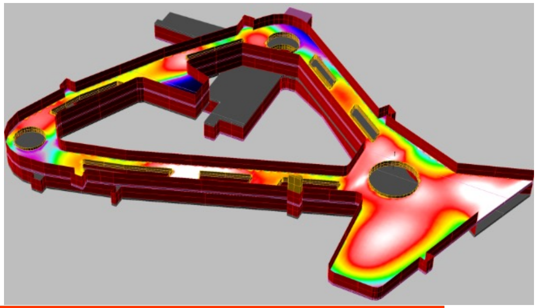
Coordination: David Geisler-Moroder, Bartenbach, Austria

Focus on the application of technical innovations in the field of integrated lighting solutions in practitioners’ workflows. Bring findings onto the desktops of designers by integration into widely used software tools, standards and codes, and design guidelines.









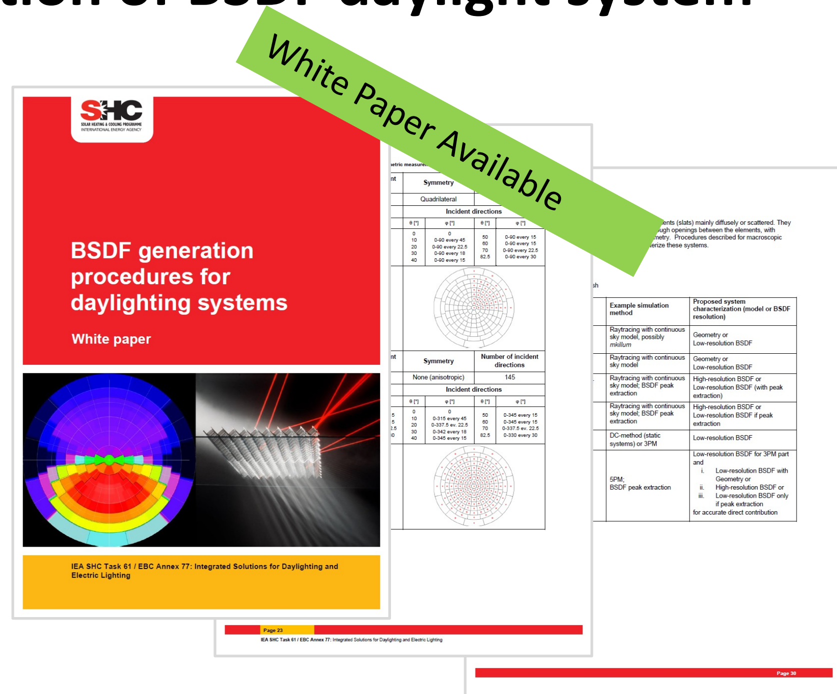
Workflows and software for the design of integrated lighting solution

- Example Design projects
  - Bartenbach Design office
  - DIAL Corporate Building
  - CABR NZEB Office Building
- Evaluation of design workflows as applied in 6 different design compan
- Review of standardized workflows
- Comparison of 12 simulation software engines

Contents

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Façade Photometry: Standardization of BSDF daylight system requirements



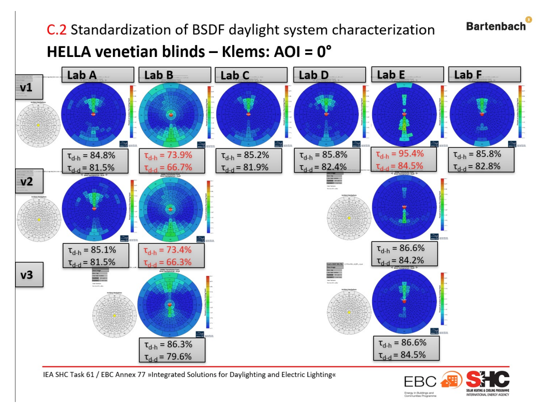
- **Whitepaper** on BSDF data generation for daylighting systems as basis for standardization.

  Which

  - angular resolution,
  - characterization, and
  - generation method

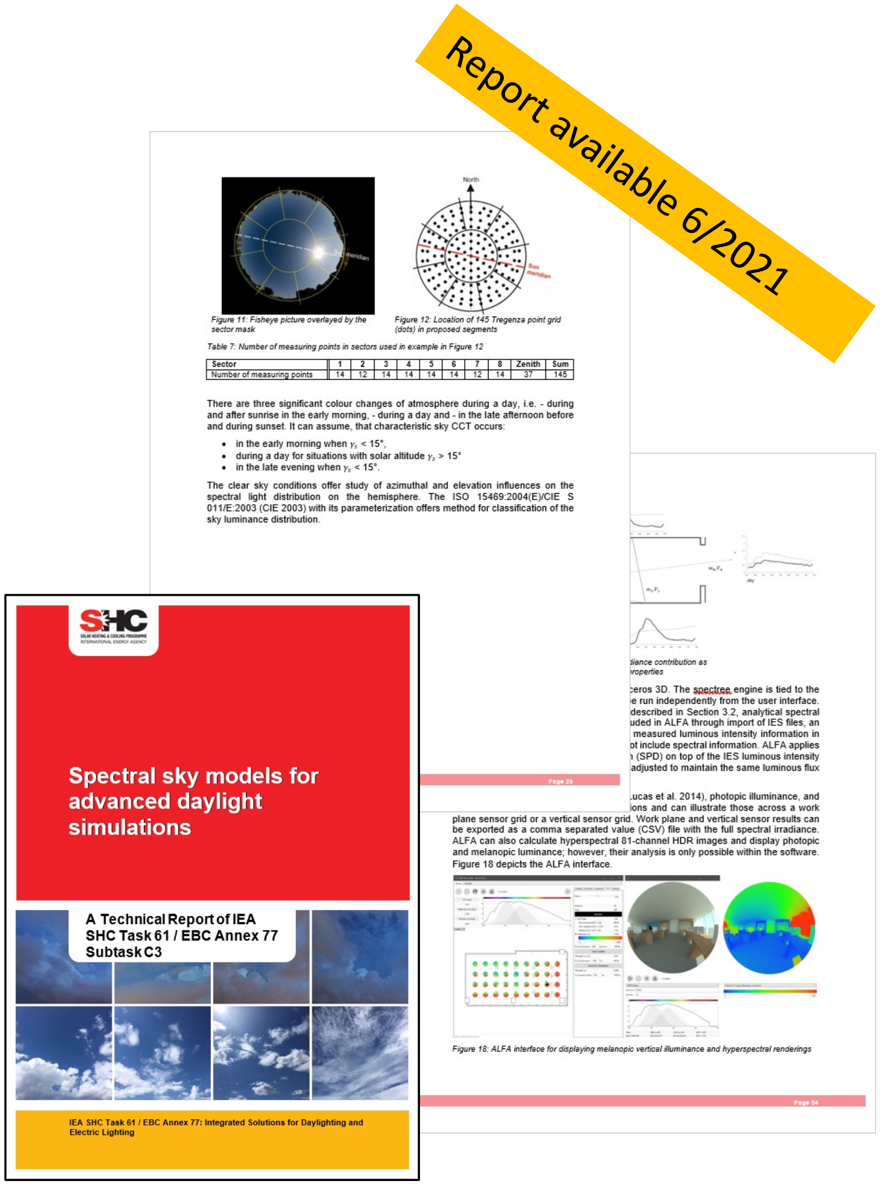
  for which system and application.

- **BSDF round robin test / quality check:** Measurements in 9 labs on venetian blind system and fabric screen and comparison of datasets in simulation.

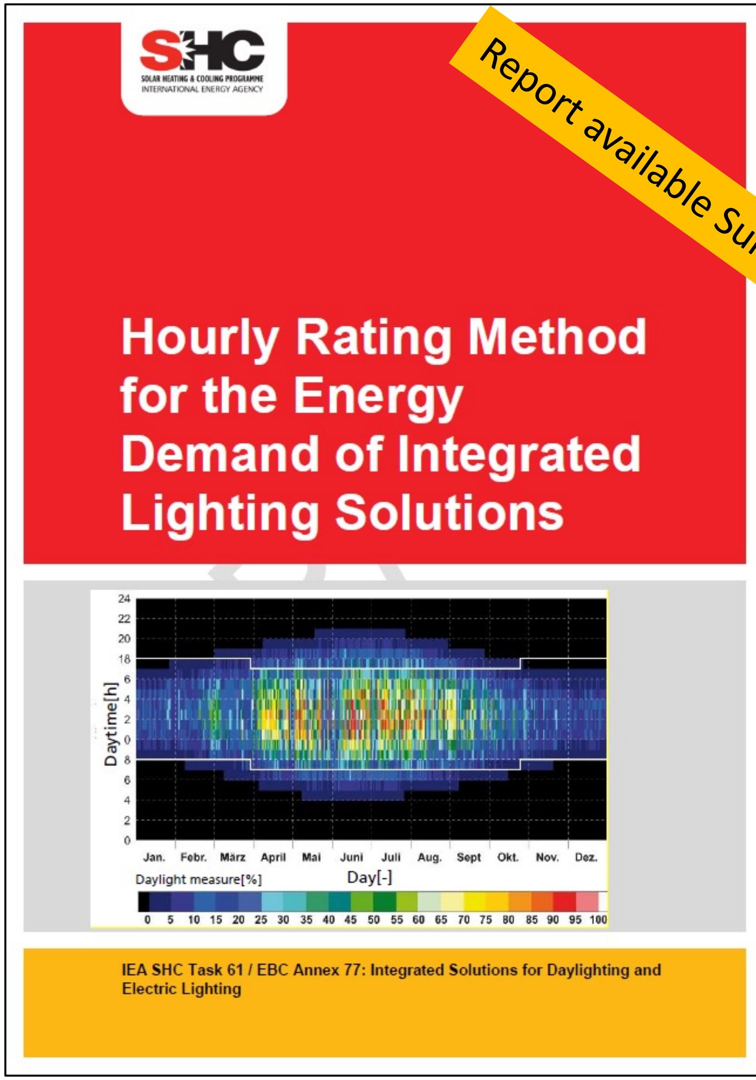


Spectral sky models

- For later inclusion of spectral characteristics / colour of daylight in the design process and tools
- Data from different location (Berlin, Beijing, Singapore, Bratislava, …)
- Supplementation of the current sky models with spatial color temperature information.



Hourly based energy rating of integrated solutions


SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Hourly Rating Method for the Energy Demand of Integrated Lighting Solutions

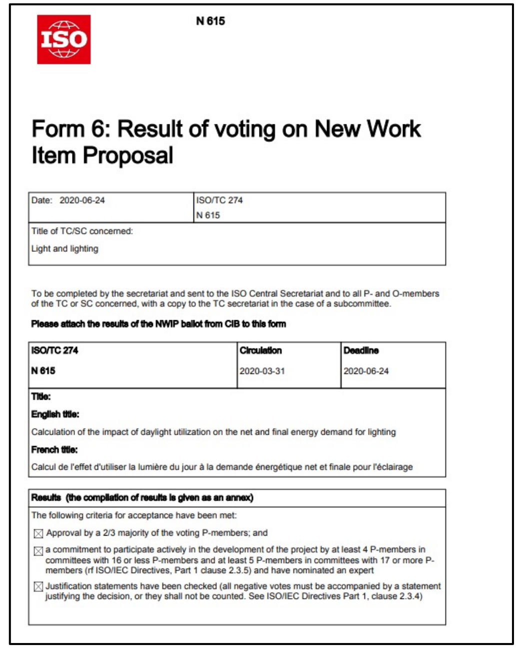
IEA SHC Task 61 / EBC Annex 77: Integrated Solutions for Daylighting and Electric Lighting

Report available Summer/2021

Hourly based energy rating of integrated solutions

Standardization

- Matched to hourly approaches in other trades (building skin, HVAC)
- Replacement for / addition to established annual methods
- ISO TC 274 “Light and Lighting” **Extension of ISO 10916**


N 615

Form 6: Result of voting on New Work Item Proposal

Date: 2020-06-24	ISO/TC 274 N 615
Title of TC/SC concerned: Light and lighting	

To be completed by the secretariat and sent to the ISO Central Secretariat and to all P- and O-members of the TC or SC concerned, with a copy to the TC secretariat in the case of a subcommittee.

Please attach the results of the NWIP ballot from CIB to this form

ISO/TC 274 N 615	Circulation 2020-03-31	Deadline 2020-06-24

Title:

English title:

Calculation of the impact of daylight utilization on the net and final energy demand for lighting

French title:

Calcul de l'effet d'utiliser la lumière du jour à la demande énergétique net et finale pour l'éclairage

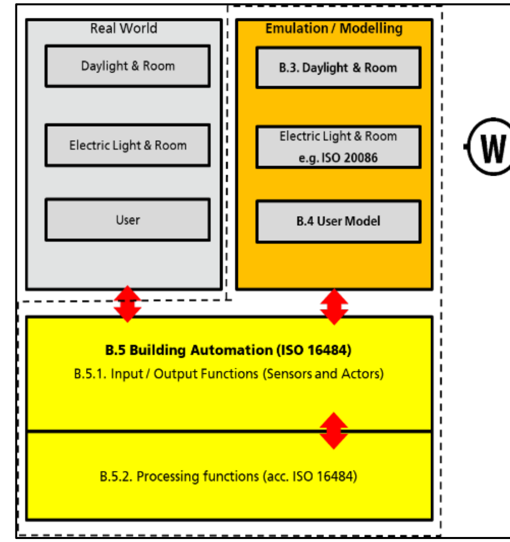
Results (the compilation of results is given as an annex)

The following criteria for acceptance have been met:

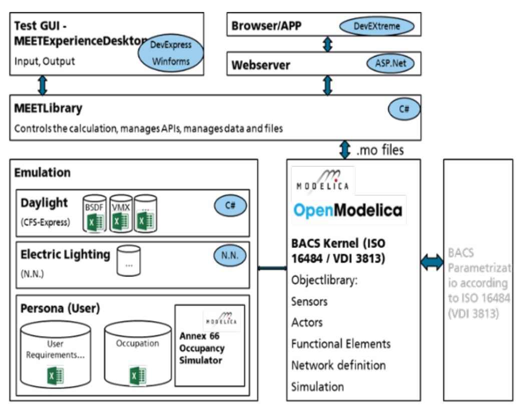
☒ Approval by a 2/3 majority of the voting P-members; and

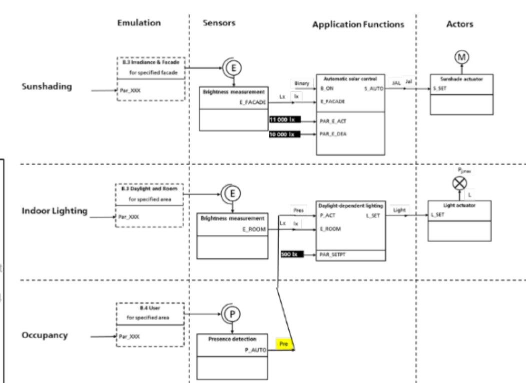
☒ a commitment to participate actively in the development of the project by at least 4 P-members in committees with 16 or less P-members and at least 5 P-members in committees with 17 or more P-members (rf ISO/IEC Directives, Part 1 clause 2.3.5) and have nominated an expert

☒ Justification statements have been checked (all negative votes must be accompanied by a statement justifying the decision, or they shall not be counted. See ISO/IEC Directives Part 1, clause 2.3.4)

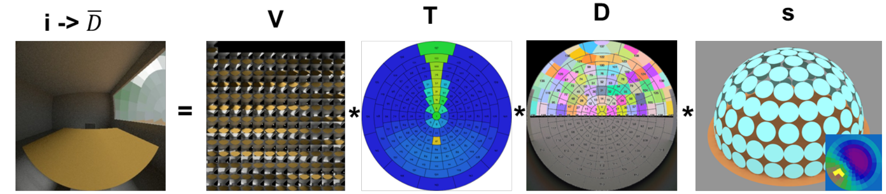


- Emulation / BACS oriented structure
- Simple web based tool with GUI for testing and learning





Hourly based energy rating of integrated solutions

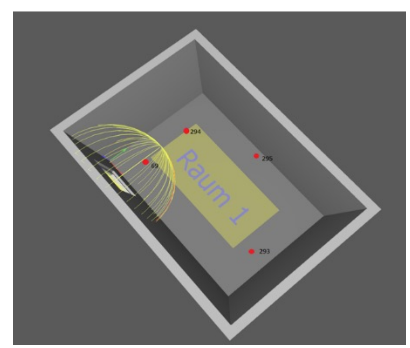


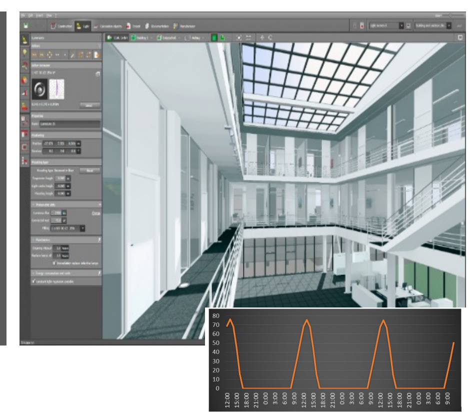
Source: IEA Task 50

DIALux Evo Integration

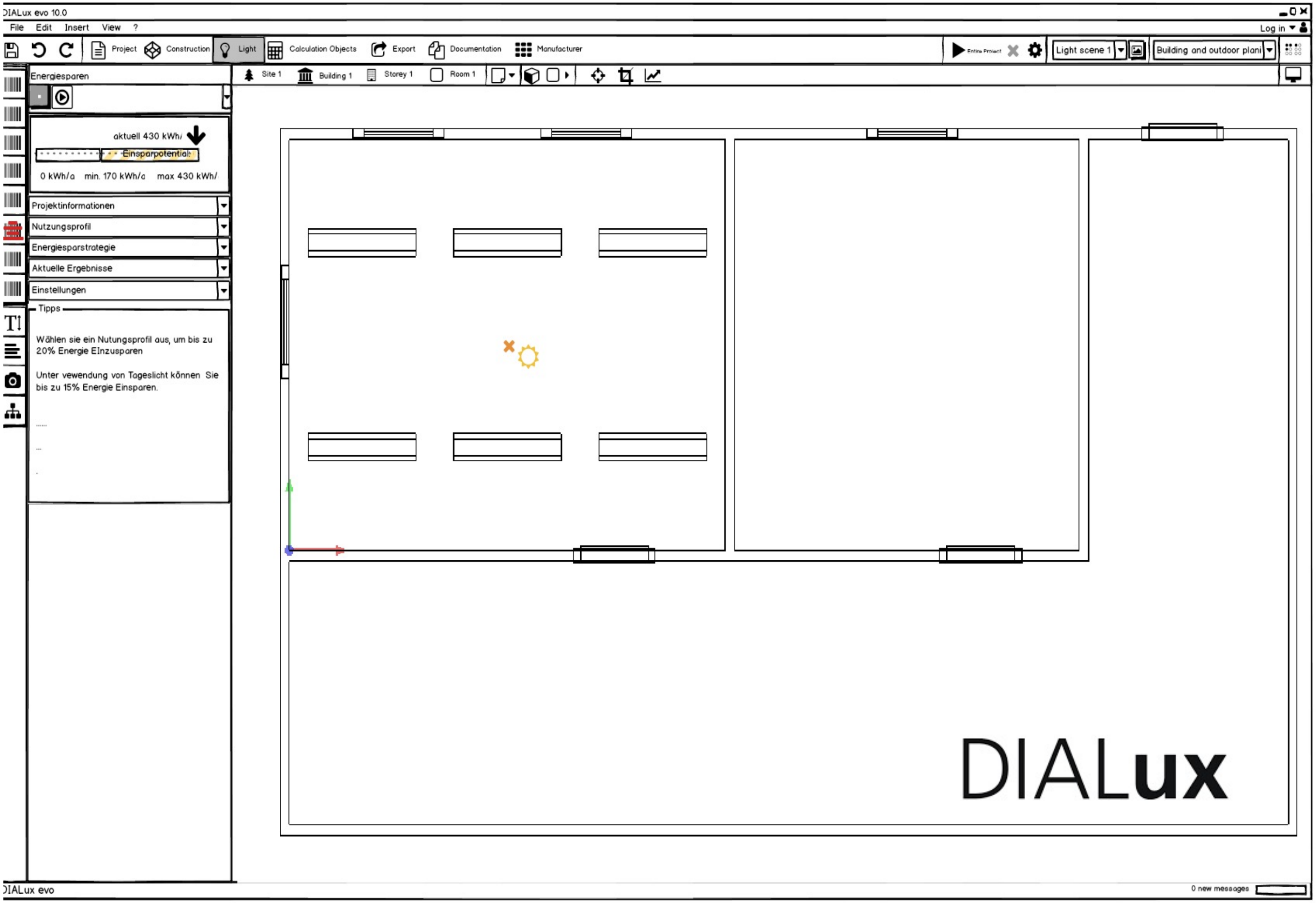
- BSDF Façade modelling
- Integration of daylight calculation ("3-Phase method")
- User journey:
  - "Energy Tachometer",
  - "Guided tour"
  - with design advice

DIALux





Hourly based energy rating of integrated solutions

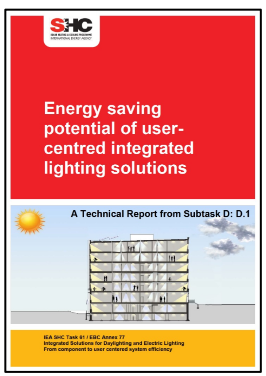


Subtask D

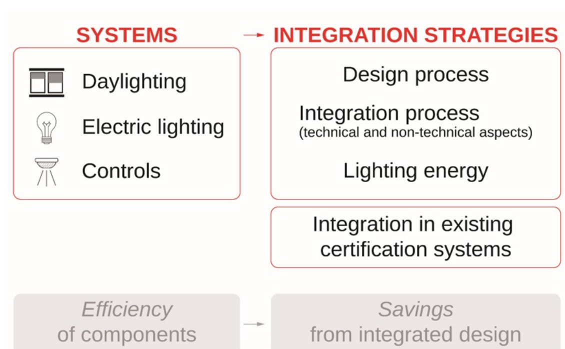
Lab and Field Study Performance Tracking

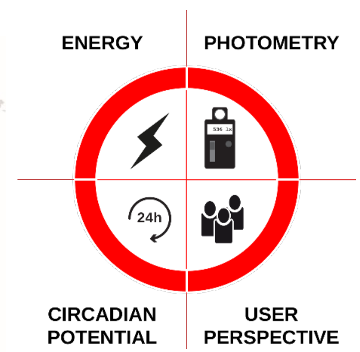
Coordination: Niko Gentile, Lund University, Sweden;
Werner Osterhaus, Aarhus University, Denmark

Demonstrate and assess typically applied concepts for integrated daylighting and electric lighting design by medium-term experiments in live-labs, supplemented by short-term investigations in controlled research laboratory environments, as well as performance tracking in “real” field studies.


Energy saving potential of user-centred integrated lighting solutions

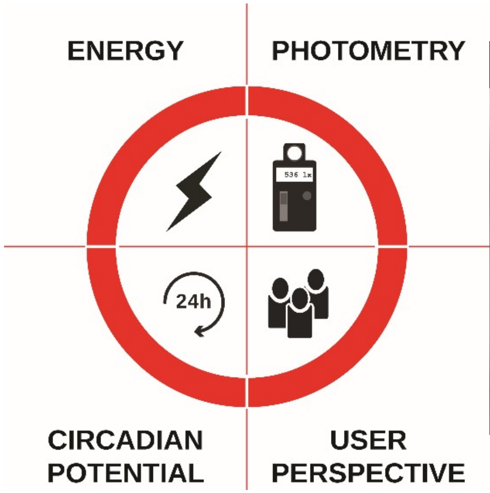
A Technical Report from Subtask D: D.1

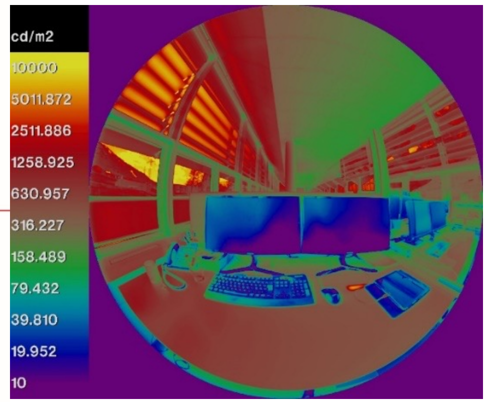


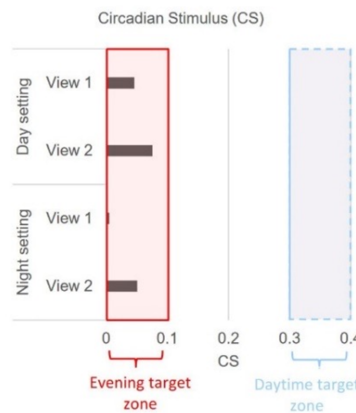


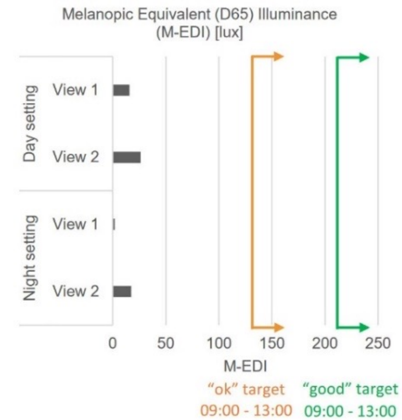
Lab and Field Study Performance Tracking

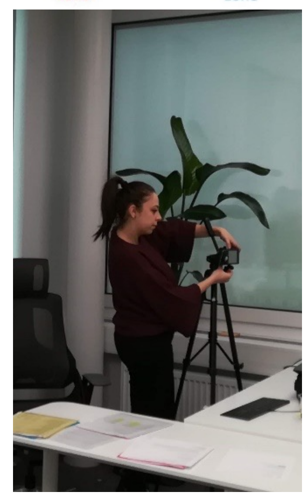
Monitoring Protocol



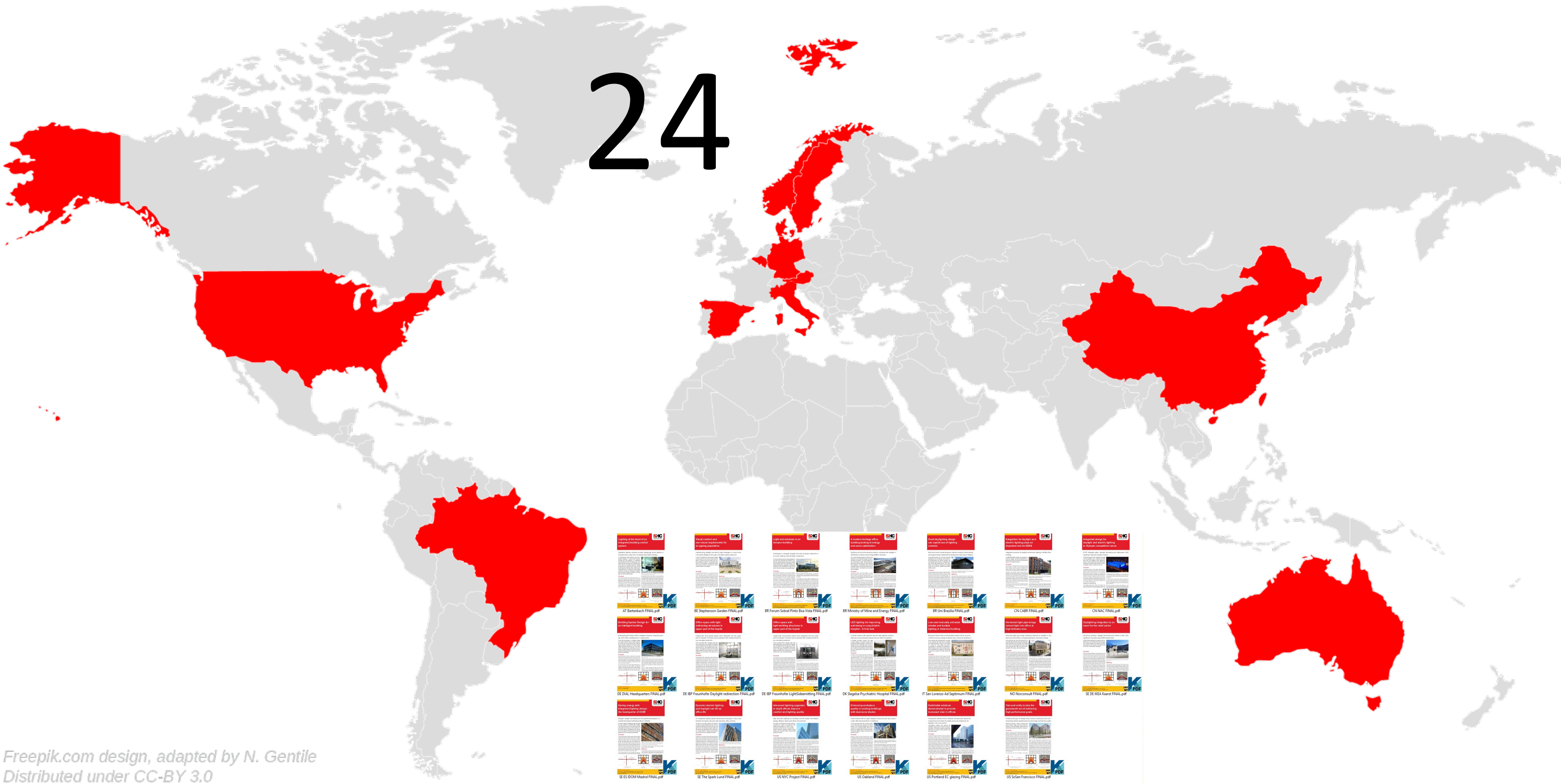








Lab and Field Study Performance Tracking



Lab and Field Study Performance Tracking

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Lab and Field Study Performance Tracking

Daylighting integration is an asset for the retail sector

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Generous windows, daylight harvesting and Human-Centric LED Lighting in the pilot project IKEA Kaarst store

At IKEA Kaarst daylight was brought into the exhibition area. This, combined with clever integration of electric lighting, has improved the shopping experience for customers and left the mark on a bunch of enthusiastic employees.

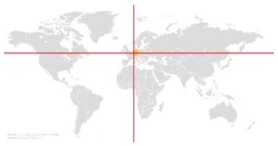
Figure 1. The IKEA shop in Kaarst as seen from the outside. The windows in the living room exhibition area can be seen at the top of the first flight of stairs.

The project

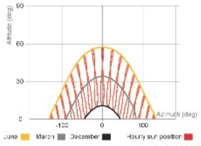
When you arrive at IKEA Kaarst, the feeling is that you are in front of yet another "blue-box" store of the famous furniture chain. But it is when you walk-in that the magic happens. In the "living room" exhibition area, large west-facing windows allows the afternoon sun illuminating sofas and tables (Fig. 2); the electric lighting is provided by LED luminaires dimmed with a daylight harvesting sensor (DHS), and a number of ceiling spot lamps. After walking through various departments, you will end up in the "home decoration" area, where fully-glazed windows provide most of the illumination and a most-welcomed connection to the outdoors; there, the electric lighting relies on traditional halogen spotlamps plus a proof-of-concept Human-Centric Lighting (HCL) consisting of LED panels with colour tuning. The light CCT changes overtime according to a predefined schedule which is intended to mimic daylight (Fig. 2).

Monitoring

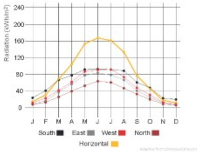
The site was first visited in February 2019, and then monitored for two weeks, slightly before the spring equinox. The field monitoring provided valuable insights as well as material to produce additional computer simulations. The simulations were used to evaluate daylight indicators such as the Daylight Autonomy (DA) or the Daylight Glare



Location: Kaarst, Germany
51.21°, 6.64°



Sun path for
Kaarst, Germany



Global horizontal and vertical radiation for
Kaarst, Germany

IEA SHC Task 61 Subtask D

Monitored by **Rafael Campama Pizarro**, Lund University
More info **Niko Gentile**, Lund University, niko.gentile@ebd.lth.se
http://www.ebd.lth.se

Switchable windows demonstrated to provide increased view in offices

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Transparent electrochromic windows increase user options for tuning their environment to satisfy personal preferences for daylight, view, and comfort

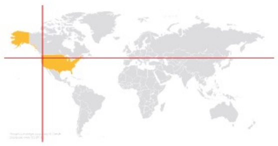
Low-emittance windows were replaced with variable-tint, electrochromic windows in forty private offices. 85% of the occupants preferred the electrochromic windows, citing increased view and visual comfort.

The project

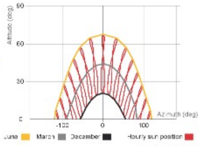
The environment next to windows is the most variable of all areas in a building and yet is the most desirable due to proximity to outdoor views and natural light. Switchable electrochromic (EC) windows can temper broad fluctuations in solar radiation and daylight by modulating tint levels between clear and darkly coloured states based on a dimming signal from automatic or manually operated controls. With adequate control, the windows can reduce heating, cooling, and lighting energy use in buildings and provide daylight and transparent views to the outdoors. To better understand user satisfaction with this novel technology, a monitored demonstration of the technology was conducted on two floors of an eight-story, 29,000 m^2 office building (vintage 1953) in Portland, Oregon, USA, where EC windows were installed on the south facade (Fig. 1-3). The EC windows were controlled automatically to meet solar control, daylight, glare, and view requirements of office

Figure 1. Exterior facade of the monitored commercial office building.

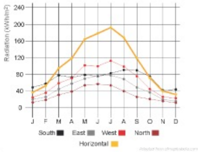
workers. The tint level could be manually overridden by the occupant at any time. Performance was compared to existing office conditions, i.e., dark tinted, dual-pane, low-emittance windows. Both the EC test and low-e reference



Location: Portland, Oregon, USA
45.50° N, 122.67° W



Sun path for
Portland, Oregon, USA



Global horizontal and vertical radiation for
Portland, Oregon, USA

IEA SHC Task 61 Subtask D

Monitored by **Luis L. Fernandes, Anothai Thanachareonkit**, LBNL
More info **Eleanor S. Lee**, Lawrence Berkeley National Laboratory, eslee@lbl.gov
https://facades.lbl.gov/demonstrations

Lab and Field Study Performance Tracking

LED lighting for improving well-being in a psychiatric hospital – A first look

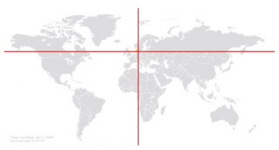
A simple solution with separate day and night lighting systems, attempts to provide better experiences for staff and patients

At Slagelse Psychiatric Hospital, they apply a simple strategy in an attempt to improve the well-being of staff and patients. In patient rooms, daylight and three downlights with a warm colour appearance provide sufficient light during the day. At night, two downlights reduce light levels and colour temperature to help create a calmer atmosphere.

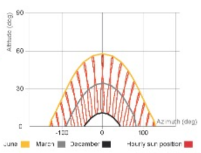
Figure 1. Psychiatric Hospital in Slagelse, Denmark: Exterior (top left), inner courtyard (bottom left) and corridor in patient ward (right) under partly overcast sky on 26 February 2020.

The project

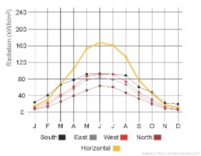
Completed in 2015, Slagelse Psychiatric Hospital (Fig. 1) is one of the largest psychiatric facilities in Denmark. The building's 44,000 m² floor area includes general and high-security wards, as well as training and research facilities. It was designed as a network of clusters with good connections between the different functions of the hospital. It achieved a silver rating in the Danish DGNB green building certification system that was first established in Germany in 2008. The lighting designers planned an extremely simple lighting design strategy in an attempt to provide better health and well-being for both patients and staff. An LED lighting system consisting of two separate circuits of luminaires was installed in the patient bedrooms and other areas of the hospital. The focus of this case study is on the patient bedrooms (Figs. 2 and 3). During the day, daylight is supplemented by three LED downlights with a correlated colour temperature (CCT) of around 2700 K providing an additional average illuminance of 250 lux on top of the daylight levels. At night, only two LED downlights in positions different from those operating during the day provide an average illuminance of just above 100 lux at a CCT of around 2000 K (measurements varied between 1750 K and 2200 K). Average daylight factor levels (DF) in the patient bedrooms are between 2 and 3 percent. A wall-mounted orientation light is installed adjacent to the base



Location: Slagelse, Denmark
55.40° N, 11.37° E



Sun path for
Copenhagen, Denmark
(55.67° N, 12.52° E)



Global horizontal and vertical radiation for
Copenhagen, Denmark
(55.67° N, 12.52° E)

IEA SHC Task 61 Subtask D

Monitored by **W. Osterhaus, I. Erhardtsen, M. Gkaintatzi-Masouti, K. Nielsen and F. Dobos**
More info: **Prof. Werner Osterhaus,** Aarhus University, werner.osterhaus@cae.au.dk

Office space with light-emitting structures in upper part of the façade

Large-scale micro-optical panels were integrated into the upper part of a façade. The lower part is operated with venetian blinds for sun and glare protection.

At the Fraunhofer IBP in Stuttgart, large scale light-emitting panels were integrated into glazing units and integrated into the upper part of the façade of a lab room. The evaluation of the performance of the lighting conditions and the energy related parameters were compared to a second identical room, with conventional lighting.

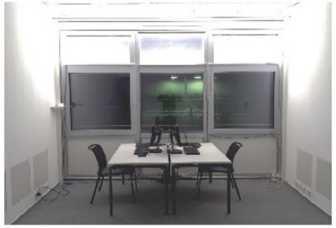
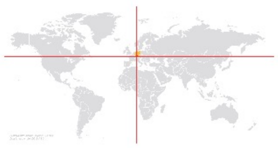


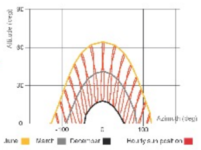
Figure 1. The lab room seen from the inside. The light-emitting structures are placed on the top part of the windows and provide illumination to the room interior.

The project

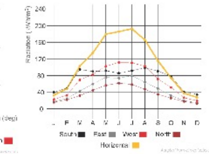
This case study is part of a bigger project project called TaLed, which was funded by the Federal Ministry for Economic Affairs and Energy (BMWI) (Project Management Jülich). The main purpose of TaLed was to improve the energy efficiency, life cycle balances and indoor comfort by employing micro-structured optical components for daylighting and electrical lighting. For this case study, a micro-optical structure, namely - Light-emitting structures, have been optimized for redirecting glare-free artificial light deeply into the building interior. The structure is placed on the surface of transparent substrates, which emit laterally injected LED light on one side only,. In this use case, large scale micro-optical panels were integrated into glazing units and placed into the upper part of the façade of a lab room at FHG-IBP (Figure 1). On the lower part of the window a standard venetian blind is being operated for sun and glare protection. To evaluate system performance the lighting conditions and the energy related parameters are compared to a second identical room, which has



Location: Stuttgart, Germany
48.74° N, 9.10° E



Sun path for
Stuttgart, Germany



Global horizontal and vertical radiation for
Stuttgart, Germany

IEA SHC Task 61 Subtask D

Monitored by **Carolin Hubschneider, Yuen Fang and Daniel Neves Pimenta**
More info **Jan de Boer,** IBP Fraunhofer, jan.deboer@ibp.fraunhofer.de

Lab and Field Study Performance Tracking

Light and shadows in an Amazon building

Challenges to integrate daylight and solar protection elements in an iconic building of the Brazilian modernism

In a representative Amazon building daylight use and solar control elements are examined. Occupants are satisfied with the indoor space, despite some changes done to the original design. Computational simulations suggested good daylighting design overall, with little risk for glare occurrence, as in the intention of the original design.

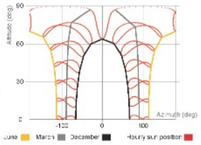
Figure 1. Forum Sobral Pinto building.

The project

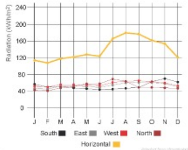
Forum Sobral Pinto (Figure 1) is an important building in Boa Vista City, capital of Roraima state, extreme North of Brazil. Located close to Equator line, immersed in Amazon Forest, the place serves to the local judiciary authority. The Forum Sobral Pinto was built in 1979, designed by Severiano Mário Porto - an icon of Brazilian modernism architecture -, internationally recognized as the "architect of the Forest "or the "architect of the Amazon". Elected man of the year by the French magazine *L'Architecture d'Aujourd'hui* in 1987, he developed in the Amazon a design with its own identity, using resources such as integration and use of local bioclimatic potential, with focus on cost optimization, renewable materials, and regional techniques. In the Forum Sobral Pinto building, Severiano Mário Porto applied bioclimatic strategies – like fixed solar shading elements - with impressive quality, while the limited depth of the building still allowed for abundant daylight penetration.

The building has an area of 5686 m^2 distributed in four floors (including an underground one). All the windows are oriented Northeast and Southwest, with fixed concrete elements used as solar shading (Figure 2). Originally, these windows had a single glass, but solar and light control films were added later for privacy and security. The windows films are of smoked type, with 50% of light transmittance. Such modification represents a major change in the original daylighting design by Severiano Mário Porto.

Location: Boa Vista, Roraima, Brazil
-11.99°, -84.14°



Sun path for
Boa Vista, Roraima, Brazil



Global horizontal and vertical radiation for
Boa Vista, Roraima, Brazil

IEA SHC Task 61 Subtask D
Monitored by Ayana Dantas de Medeiros, **Derick Lucas, Leslie Oliveira, Nathalya Melo, Poliana Pires,** Lab of Environmental Control and Energy Efficiency - LACAM, UnB
More info **Cláudia Naves David Amorim**, University of Brasilia, clamorim@unb.br

Lighting at the heart of an integrated building control system

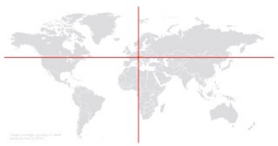
Integrated lighting solutions enable biologically active lighting in the glare-free Living Lab in the Bartenbach R&D building

In the Bartenbach R&D building a high level of daylight integration is realized while maintaining glare and heat protection. In combination with workstation-zoned LED lighting with color temperature and intensity control adapted to the time of day, the occupants experience a lighting environment that provides both visual comfort and biologically activating effects satisfying individual preferences. To exploit the energy effects of integral concepts, the heating and ventilation trades are also controlled in addition to the daylight and artificial lighting trades.

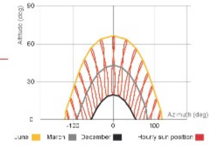
Figure 1. Careful daylighting design is integrated with CCT tuning at the Bartenbach headquarter in Aldrans, Austria.

The project

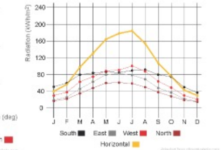
Upon entering the R&D office building of Bartenbach, the large, south facing windows together with north-oriented skylights are identified as prominent feature, ensuring a high daylight level in the office. 200 m² of office space are divided into an open-plan office, two individual offices and a meeting room (Fig. 2). To avoid disruptive effects of direct sunlight on the workplaces, external static daylight deflecting louvres are installed, the size and spacing of which were specially arranged and dimensioned for the geographical location of the building. The electrical lighting of the workplaces and transit zones is realized with a ceiling-integrated LED lighting system equipped with patented freeform surface reflectors developed by Bartenbach. With the artificial lighting, glare-free illumination of the workplaces is ensured by means of longitudinal glare control and asymmetrical beam characteristics. In addition, the luminaire arrangement provides uniform illumination of the workstations and prevents the user from shading the work surface. Via illuminance sensors and passive infrared sensors, the artificial light is automatically switched or



Location: Aldrans, Austria
47.24°, 11.46°



Sun path for
Aldrans, Austria



Global horizontal and vertical radiation for
Aldrans, Austria

IEA SHC Task 61 Subtask D
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Lab and Field Study Performance Tracking

Lessons learned

- **24 case studies** provided as factsheets for a wide audience
- **Energy use is reduced by a factor a four** compared to current installations (5 kWh/m^2a vs 20 kWh/m^2a for offices) thanks to re-lamping, re-commissioning shading/lighting systems (including training and fine tuning), and controls
- Systems eliciting circadian response (**dynamic dimming and color tuning**) are **very popular** and appreciated by users
- However, there is a **risk of energy rebound associated with these systems**
  - They are designed for electric lighting conditions only (no daylighting integration!)
  - They must deliver around 1500 lx on the horizontal to elicit some response at vertical eye position
  - Low efficiency LED are often used (80 lm/W or so)
- **View out is a determinant factor** for appreciation; view out ≠ daylight > openings with different purposes are proposed (e.g. top part for daylight, bottom section for view out)
- **The occupant saves energy**, not the system: training, education, fine tuning!

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Daylighting of Non–Residential Buildings

Position Paper

January 2019

Contents

This document was prepared by Dr.-Ing. Jan de Boer of Fraunhofer Institute for Building Physics, Stuttgart, Germany and Operating Agent of *SHC Task 50: Advanced Lighting Solutions for Retrofitting Buildings and SHC Task 61: Integrated Solutions for Daylighting and Electric Lighting* of the Solar Heating and Cooling Technology Collaboration Programme.

The lack of advanced energy calculation and rating method impedes the design of innovative lighting installations integrating daylighting into "Human Centric Lighting" and "Smart & connected Light" concepts.

Actions Needed

The following actions by governmental, non-governmental organization ("NGO") and private entities could significantly drive this market up.

Governments

- *Daylight as "renewable energy source":* Recognition of daylight – which can be sufficiently quantified as an offset for electric lighting – as a "renewable energy source" included for instance in subsidy programs as a known from other market sectors (PV, wind, etc.).
- *Revision of ordinances:* Revision of ordinances to demand the incorporation of technically working and economically advantageous daylighting solutions:
  - *Floor plans/architecture:* Where not yet implemented, specification of a minimal ratio of window to floor area of spaces (for instance in central Europe between 1/8 – 1/10). Specifications for minimum view out.
  - *Façade technology:* Inclusion of light redirection technologies in the façade. Selection of daylighting supportive combinations of glazing and sunshading/ glare protection devices.
  - *Building Management Systems:* Usage of daylight dependent electric lighting controls. Control of sunshading/glare protection dependent on indoor space occupancy sensing (visual comfort driven when occupied, solar gain driven when unoccupied: i.e., maximum gains in winter, minimum in summer).

NGOs and private public partnerships

- *Sustainability certificates:* Use sustainability certificates to promote daylighting. Introduce daylighting if not included yet or revisit existing older certificates and update.
- *Memoranda of understanding of key players in the market:* Agreement on reduction goal for lighting energy consumption with a fixed time horizon. Daylight will have to play a key role in this. A recent Swiss initiative to reduce by half the energy consumption for lighting by 2025 could serve as a template, https://www.minergie.ch/media/mm_minergie_licht_2018_20180913_1.pdf

Private sector (design, industry)

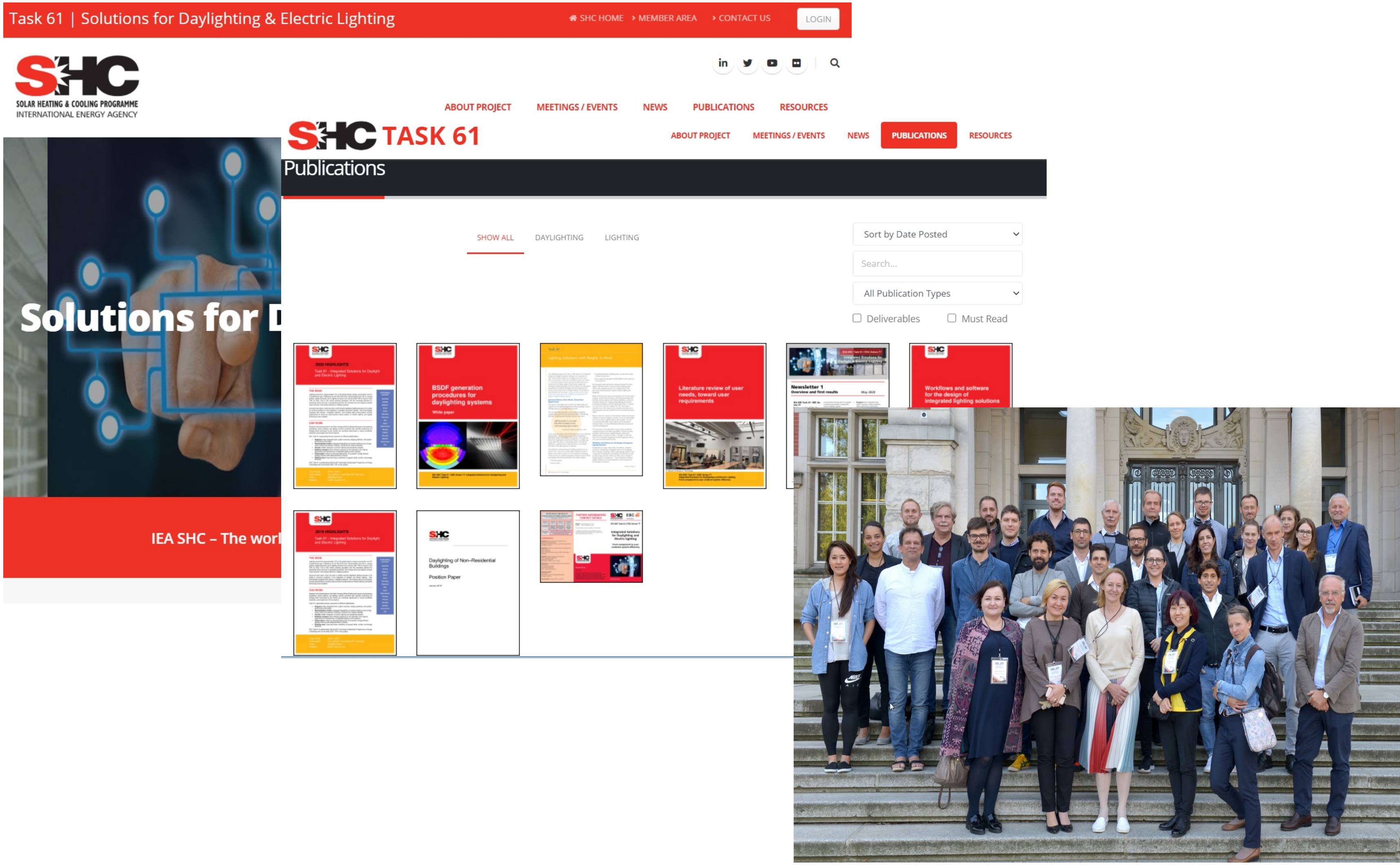
- *Design process:* Introduction of processes ensuring certain daylight quality levels (e.g., by parametric, automated design tools). Deployment of concepts from new daylighting standards like EN 17037 "Daylight of Buildings."
- *Design tools:* Establishment of more refined rating methods in standards and design tools supporting new product features and integrated building management.
- *Integrating day- and electric lighting:* Better integration of daylighting and electric lighting in a holistic lighting design approach is an important lever for increasing efficiency and better matching lighting to the user's needs (refer also to http://task61.iea-shc.org/)


WORK IN PROGRESS


Finish line
Just ahead


STAY TUNED

Follow us: http://task61.iea-shc.org/ …and of course …



…use light intelligently.

Alexander Lervik,
Designer,
Stockholm