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

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
„The World is shining. Unfortunatly.“

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

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

- **Facade**
  - 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

- **General Trend:** 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

High Integration
- User Centred Light ...
  ...at high system efficiency
- Daylight as template for electric lighting
  (visual / non visual)
- Linked markets / industries: electric light & facade

Better understanding of user perspective

X

New Technologies and tools

Better lighting with less energy, damp rebound effect.

Objective

Electric Lighting

High Integration

Day-lighting

Better understanding of user perspective

X

New Technologies and tools

Better lighting with less energy, damp rebound effect.

Objective

Electric Lighting

High Integration

Day-lighting

Better understanding of user perspective

X

New Technologies and tools

Better lighting with less energy, damp rebound effect.
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 practitioners
(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

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Who is behind the activity?

About 35 Experts from 14 countries

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

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

Flicker may be divided into two types. One 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 obesees with photomissive 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. Those 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 52, 47–53


3.6 Spatial frequencies

In the spatial domain, one identified source of visual discomfort is when images have Fourier amplitude spectra that contain higher frequencies (1/f) relative to natural scenes. Essentially, 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 response, and indicator of a workflow-related state and frontal attention.

3.6.1 References


3.7 Temporal changes

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

In a study where the direct component of a direct-indirect luminance 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, and 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


User perspective and requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Daylight Measure</th>
<th>Standard value</th>
<th>Electric light Measure</th>
<th>Standard value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Workplace illumination general</strong></td>
<td>Target illuminance of daylight provision from windows</td>
<td>≥ 300 lux on the working place level</td>
<td>Mean E_n on the desk</td>
<td>Together with daylight ≥ 500 lux</td>
</tr>
<tr>
<td>Spaces with skylights</td>
<td>as for windows but ≥ 95% of the space area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Workplace illumination Visual demanding</strong></td>
<td>daylight provision from windows</td>
<td>≥ 750 lux on the desk</td>
<td>Mean E_n on the desk</td>
<td>1030 lux</td>
</tr>
<tr>
<td><strong>Workplace illumination homogeneity</strong></td>
<td>Minimum Target illuminance of Daylight provision from windows</td>
<td>≥ 100 lux on the working level in room</td>
<td>Uniformity U_{s(min)} on the desk</td>
<td>≥ 0.6</td>
</tr>
<tr>
<td><strong>Workplace illumination homogeneity Visual demanding</strong></td>
<td>Minimum Target illuminance of Daylight provision from windows</td>
<td>≥ 200 lux on the working level in room</td>
<td>Uniformity U_{s(min)} on the desk</td>
<td>≥ 0.7</td>
</tr>
<tr>
<td>Movement area illumination</td>
<td>No measure</td>
<td>Low daylight illuminance is accepted</td>
<td>Mean E_n</td>
<td>200 lux</td>
</tr>
<tr>
<td>Movement area illumination homogeneity</td>
<td>No measure</td>
<td>Low daylight illuminance homogeneity is accepted</td>
<td>U_{s} (E_{min} E_{mean})</td>
<td>0.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Colour of light in general</th>
<th>No measure</th>
<th>Natural variation of colour of daylight is appreciated</th>
<th>CCT (K)</th>
<th>3000 – 6000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour of light Wards</td>
<td>No measure</td>
<td>blue and green tint of window glass should be avoided</td>
<td>CCT (K)</td>
<td>4000 ± 5% 5000</td>
</tr>
<tr>
<td>Workplace colour rendition</td>
<td>Colour rendering for window glass</td>
<td>hue shift ≤ 30</td>
<td>CRI (additional R_{2})</td>
<td>≥ 60</td>
</tr>
<tr>
<td>Workplace colour rendition</td>
<td>Colour rendering for window glass</td>
<td>hue shift ≤ 10</td>
<td>CRI (additional R_{2})</td>
<td>≥ 60</td>
</tr>
<tr>
<td>View out to the outside from the workplace</td>
<td>Width of the view</td>
<td>&gt; 14°</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Length of the view</td>
<td>&gt; 6m</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Number of view layers (ground, landscape, sky)</td>
<td>Minimum landscape layer is visible</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Glare</td>
<td>Daylight glare probability PDP ≤ 0.5</td>
<td>UGR</td>
<td>≤ 19</td>
</tr>
<tr>
<td></td>
<td>Lumina in the visual field</td>
<td>Max. luminance of the window surface for workplaces in neighborhood of window</td>
<td>≤ 4000 cd/m²</td>
<td>Max. luminance at gamma &gt; 60°</td>
</tr>
<tr>
<td></td>
<td>Repeating luminance contrasts</td>
<td>Spatial frequency on the window surface</td>
<td>Avoid strong luminance contrast in the medium frequencies (0.2 – 0.8)</td>
<td>Multishadows from lamps Mean illuminance at surface level</td>
</tr>
<tr>
<td>Homogeneity of light-emitting surface</td>
<td>L/(L(90%))</td>
<td></td>
<td></td>
<td>L/(10%)/L_{mean}</td>
</tr>
<tr>
<td>Non-visual effects of light (daytime work)</td>
<td>Daylight is recommended wherever possible.</td>
<td></td>
<td></td>
<td>Circadian stimulus [CS]</td>
</tr>
<tr>
<td>Non-visual effects of light (shift work)</td>
<td></td>
<td></td>
<td></td>
<td>Circadian stimulus [CS]</td>
</tr>
</tbody>
</table>

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”.

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
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 environment in Home office
– online survey

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Preliminary Home office results Brazil: Students
LIGHTING CONDITION IN THE WHOLE HOME OFFICE ROOM NOW

<table>
<thead>
<tr>
<th>Satisfaction with daylight?</th>
<th>Satisfaction with electrical lighting?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all Satisfied</td>
<td>Very satisfied</td>
</tr>
<tr>
<td>0 (0%)</td>
<td>32 (34.4%)</td>
</tr>
<tr>
<td>1 (3.2%)</td>
<td>21 (22.6%)</td>
</tr>
<tr>
<td>2 (7.5%)</td>
<td>19 (20.4%)</td>
</tr>
<tr>
<td>3 (11.8%)</td>
<td>7 (7.5%)</td>
</tr>
<tr>
<td>4 (22.6%)</td>
<td>11 (11.8%)</td>
</tr>
<tr>
<td>5 (20.4%)</td>
<td>21 (22.6%)</td>
</tr>
<tr>
<td>6 (34.4%)</td>
<td>32 (34.4%)</td>
</tr>
<tr>
<td>7 (11.4%)</td>
<td>19 (20.4%)</td>
</tr>
</tbody>
</table>

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?)

<table>
<thead>
<tr>
<th>Satisfaction with external view from window?</th>
<th>Satisfaction with the general light level in the room?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all Satisfied</td>
<td>Very satisfied</td>
</tr>
<tr>
<td>0 (0%)</td>
<td>1 (1.1%)</td>
</tr>
<tr>
<td>1 (7.7%)</td>
<td>2 (2.1%)</td>
</tr>
<tr>
<td>2 (14.3%)</td>
<td>8 (8.4%)</td>
</tr>
<tr>
<td>3 (17.6%)</td>
<td>11 (11.6%)</td>
</tr>
<tr>
<td>4 (17.6%)</td>
<td>20 (21.1%)</td>
</tr>
<tr>
<td>5 (13.7%)</td>
<td>35 (38.8%)</td>
</tr>
<tr>
<td>6 (21.1%)</td>
<td>18 (18.9%)</td>
</tr>
<tr>
<td>7 (28.6%)</td>
<td>18 (18.9%)</td>
</tr>
</tbody>
</table>

IEA SHC Task 61 / EBC Annex 77 Integrated Solutions for Daylight and Electric Lighting
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: Examples of new technology opportunities available.
Survey on opportunities and barriers in lighting controls

New technology opportunities available

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

Survey on opportunities and barriers in lighting controls

Report available 6/2021

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Figure 7: Answers from new technology opportunities available.

Figure 8: Answers from new technology opportunities available.

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

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

Report available 6/2021

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

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

- Review of standardized workflows

- Comparison of 12 simulation software engines

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

Hourly Rating Method for the Energy Demand of Integrated Lighting Solutions

Report available Summer/2021

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

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

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Hourly based energy rating of integrated solutions

DIALux Evo Integration

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

Source: IEA Task 50
Available 2021

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Hourly based energy rating of integrated solutions

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
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.
Lab and Field Study Performance Tracking

Monitoring Protocol

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Lab and Field Study Performance Tracking

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Lab and Field Study Performance Tracking

IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Lab and Field Study Performance Tracking

Daylighting integration is an asset for the retail sector

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

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 allow the afternoon sun illuminating sofas and tables (Fig. 2), the electric lighting is provided by LED luminaires dimmed with a daylight harvesting sensor (DA) 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 spot lamps plus a proof-of-concept Human-Centric Lighting (HCL) consisting of LED panels with colour tuning. The light CCT changes overtime according to a pre-defined schedule which is intended to mimic daylight (Fig. 2).

Monitoring
The site was first visited in February 2016, and then monitored for two weeks, sightly 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

Switchable windows demonstrated to provide increased view in offices

Transparent electrochromic windows increase user options for tuning their environment to satisfy personal preferences for daylight, view, and 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, 29,600 m² office building (vintage 1955) in Portland, 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 workers. The tint levels 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

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

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 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 2009. 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 illumination 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 illumination 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 1.2 and 3 percent. A wall-mounted orientation light is installed adjacent to the base.

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.

The project

This case study is part of a bigger project project called Telao, which was funded by the Federal Ministry for Economic Affairs and Energy (BMBF) (Project Management Jülich). The main purpose of Telao was to improve the energy efficiency, life cycle balance 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 glass-free artificial light deeply into the building interior. The structure is placed on the surface of transparent substrates, which emit internally reflected LED light on one side only. In this case study, large scale micro-optical panels were integrated into glazing units and placed into the upper part of the façade of a lab room at Fraunhofer 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...
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.

**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 1977, designed by Severiano Mário Porto – an icon of Brazilian modernist 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

![Figure 1. Forum Sobral Pinto building](image)

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 5986 m² 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.

**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.

**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 deflection louvres are installed, the size and spacing of which were specially arranged and dimensioned for the

![Figure 1. Comfortable daylighting design is integrated with CCT tuning at the Bartenbach headquarter in Airth, Austria.](image)

**IAE SHC Task 61 Subtask D**

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IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
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/m²a vs 20 kWh/m²a 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!
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.
  - *Facade technology:* Inclusion of light redirection technologies in the facade. 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 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 the energy consumption for lighting by 2025 could serve as a template: [https://www.minergie.ch/media/mm_minergie_light_2018_20180913_1.pdf](https://www.minergie.ch/media/mm_minergie_light_2018_20180913_1.pdf)

**Private sector (design, industry)**
- **Design process:** Introduction of processes ensuring certain daylight quality levels (e.g., 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/](http://task61.iea-shc.org/))
IEA SHC Task 61 / EBC Annex 77 „Integrated solutions for daylight and electric lighting“
Follow us: [http://task61.iea-shc.org/](http://task61.iea-shc.org/) ...and of course ...
...use light intelligently.