Daylight driven and user centered lighting and energy management

Wilfried Pohl¹, David Geisler-Moroder¹

¹ Research Department, Bartenbach GmbH, Austria
• iNSPiRe
  Refurbishment of residential and tertiary buildings

• IEA SHC Task 56
  Building Integrated Solar Envelope Systems for HVAC and lighting
Light and information

Seeing is a mental process
Impact of light on humans

- visual conditions to 'see'
- mood/emotions
- mental performances
- physical processes
- well-being, health

LIGHT is the most important timer!
You need light to ........

• See (visual perception).....
• feel good (emotion, well-being).....
• create special atmospheres, appearances, (emotion).....
• enjoy the beauty (emotion).....
• trigger your circadian rhythm (health).....
• create preventive and therapeutic effects (long term health effects)).....
• relax and to activate (short term health effects).....
• optimize working conditions (>performance)
• Etc.

Most effects of light are unconscious and not perceivable!
Neurophysiological background
Identified non-visual light effects

Modification of

- **Circadian (physiological) parameters** (melatonin, cortisol, core body temperature, heart rate)

- Feeling of Sleepiness / Alertness

- **Cognition** (attention, memory, problem solving)

- Mood
daylighting requirements

visual
- amount of daylight/daylight distribution: guide daylight into the depth of the building
- glare protection: provide visual comfort
- view to the outside: allow a good contact to the outside
- **Non-visual effects:**
  
  Sleepiness / Alertness (circadian)
  Cognition
  Mood

energetic
- shade the solar heat in summer
- provide solar gains in winter
Integrated lighting control scheme

Need for an integral control for day- and artificial light

Consideration of
- Visual and melanopic needs
- Intelligent sensor technology
- Interface human – machine
- Energy demands
Integrated lighting control scheme

- Daylight sensor
- $E_v$ on façade from sun / sky / ground; color temperature
- System settings (tilt angles)
- Daylighting system
- Daylight coefficients
- Measurement points
- Workplane illuminance from daylight
- Dimming level; color temperature
- Artificial light
- Heating / cooling period
- BMS/HVAC

Control
Circadian light: colour temperature variation

Daylight oriented

Intervention oriented (activation)

06:00  12:00  18:00

Beleuchtungsstärke  Farbtemperatur

morgens  nachmittags
Control specifications

Visual Criteria:

• mean window luminance ≤ 1000 cd/m²
• maximal window luminance ≤ 3000 cd/m²
• Illuminance at eye ≤ 1000 lux
Control specifications

**Emotional criteria:**

Evaluation of look through

(e.g. acc. DIN 14501 oder Konstantzos et al., 2015)
Non-visual criteria:

• Vertikal illuminance at eye evaluated with model

• Weighted light dose: aim: $D \geq 5000\text{wlxh}$ (weighted lux * hours)
Bartenbach R&D Office, Aldrans, AT

Comprehensive retrofit of office: daylight solution, artificial lighting solution, control, interior redesign
Bartenbach R&D Office, Aldrans, AT

**Daylight solution:** exterior louvers with varying distance between slats optimized for location, additional screen for luminance control

**Artificial lighting solution:** architecture integrated, max. 1250lx, 14W/m² installed, @ 500lx < 6W/m², CCT 2200K – 5000K

**Control:** sensors for occupancy, workplane and exterior illuminance, wind speed, temperature

**Interior design:** redesign of interior surfaces, acoustical ceiling, acoustical panels
DALEC Online Tool
www.dalec.net
Daylight and Energy

Aufenraffstore (45°) im Sichtbereich

\[ g\text{-}\text{Wert}^\perp : 22\% \]

\[ \tau_{\text{vis}}^\perp : 12\% \]

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<tr>
<th>Jahr</th>
<th>Kühlung [kWh/(m²*a)]</th>
<th>Heizung [kWh/(m²*a)]</th>
<th>Licht [kWh/(m²*a)]</th>
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Daylight and Energy

Außenraffstore (45°) oben & unten

\[ g\text{-Wert} \downarrow: 22\% \]

\[ \tau_{\text{vis}} \downarrow: 12\% \]

Tageslichtlösungen, Systeme

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\( \text{kWh/}[m^2a] \)
Daylight and Energy

Innenliegende Umlenklamelle (0°)

- g-Wert: 44%
- τ_{vis}: 57%

Kühlung [kWh/(m²*a)]
Heizung [kWh/(m²*a)]
Licht [kWh/(m²*a)]

cooling 17,7
heating 17,0
light 4,2

Tageslichtlösungen, Systeme

Conclusions

Chances

• **Integrated design and control** of daylight systems
  • Integration in BMS
  • Integration with artificial light

• increase building **energy efficiency** by
  • good daylighting (replace artificial light)
  • efficient sun shading (minimize cooling loads), e.g. block the heat while utilizing the light
  • solar gains when needed (use for heating)
Conclusions

Chances

• increase **visual and thermal comfort** by intelligent systems
  • avoiding glare and redirecting light into the room depth
  • blocking the heat and avoiding high indoor surface temperatures

• increase **health (non-visual) effects** by exploiting daylight
  • Optimizing circadian effects (light dosage)
Conclusions

CURRENT LIMITATIONS:

- complex system architecture which require a high background knowledge

- existence of equivocal lighting control schemes for lighting designers, and electrical engineers

- restricted interoperability of mostly proprietary lighting control hard- and software

- high investment and installation costs

- confusing user interfaces and troublesome user-lighting interactions

- sophisticated maintenance and high service costs
Conclusions

Risks:

- **Open buildings create severe thermal and visual comfort problems**
  - glare
  - high indoor surface system temperatures
  - overheating

- **Higher energy consumption by**
  - high solar gains (cooling loads)
  - bad shading practice and daylighting > need for artificial lighting and additional cooling
Future

- **scientific evidence** for non-visual light effects is quite weak at the moment

- more **resilient scientific basis** on non-visual light effects is needed

- By documenting the added value of biodynamic lighting, we will change the value of light from a cheap and thus unimportant issue to a **valuable part of our environment, life quality and life style**