Daylight driven and user centered lighting and energy management

Wilfried Pohl, David Geisler-Moroder
Bartenbach GmbH

In the EC-funded FP7-project 'Development of Systemic Packages for Deep Energy Renovation of Residential and Tertiary Buildings including Envelope and Systems' (iNSPiRe; URL: http://www.inspirefp7.eu/) amongst others envelope retrofitting packages have been developed. The goal was to improve the façade of these buildings by providing more accessible and affordable energy saving solutions.

Utilizing daylight in buildings is a complex task: providing sufficient and properly distributed daylight within the room, in parallel avoid any glare and discomfort, allow solar gains for heating in winter and provide sun shading to protect from overheating in summer, and finally allow a view to the outside. So the challenge is to increase the daylight utilization while at the same time controlling the visual and thermal comfort and the solar energy inputs.

To cover all these contradictory requirements, special systems are needed.

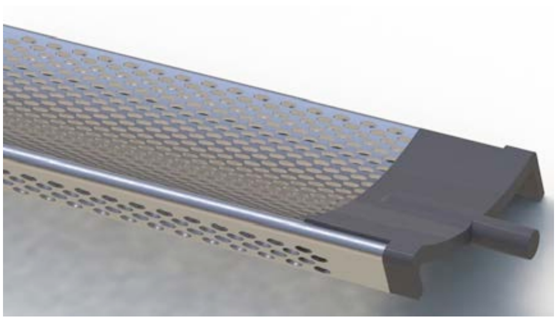


Figure: Patented lamella system evaluated in a Mock-up.

At the same time, an advanced daylight system should serve people not only for good vision but also for non-visual (biological) light effects on mood, cognitive performance, sleep and in the long-run for health. With the discovery of the photopigment melanopsin in the human retina, which photochemically has its maximal sensitivity at short wavelengths between 460-490nm and induces the suppression of the melatonin production (sleeping hormone) and thus triggers the circadian rhythm, a global hype has been provoked raising big expectations regarding the significance of (day)light for people (the so called 'human centric lighting', HCL).

Experts from diverse fields (e.g., endocrinologists, chronobiologists, physiologists, neurologists, psychiatrists, psychologists) started to investigate immediate and long-term (circadian) light effects on neurophysiological, endocrine, cognitive and mood-related parameters. Non-visual effects caused by bright light and selective light spectra at eye level subject to several exposure times and durations and previous light exposures (light history) were examined in several studies. However, the results are by far not sufficient to serve as a basis for lighting applications and thus further research is necessary.

At the moment daylight design usually is not integrated in artificial lighting design, and HCL currently focusses only on time-dependent variations of interior artificial light settings. Intelligent controls based on sensor technology are necessary, with flexible soft- and hardware allowing clever control algorithms to create the best combined (artificial and natural) illumination for the health and well-being of individuals, sometimes also be tailored to the individual.

Bartenbach and research partners at the University of Innsbruck have recently developed a dosimetric model for achieving non-visual light effects during the day as well as a circadian effective artificial light and daylight control scheme. At the moment the suitability of different daylight systems to realize this light control scheme are evaluated:

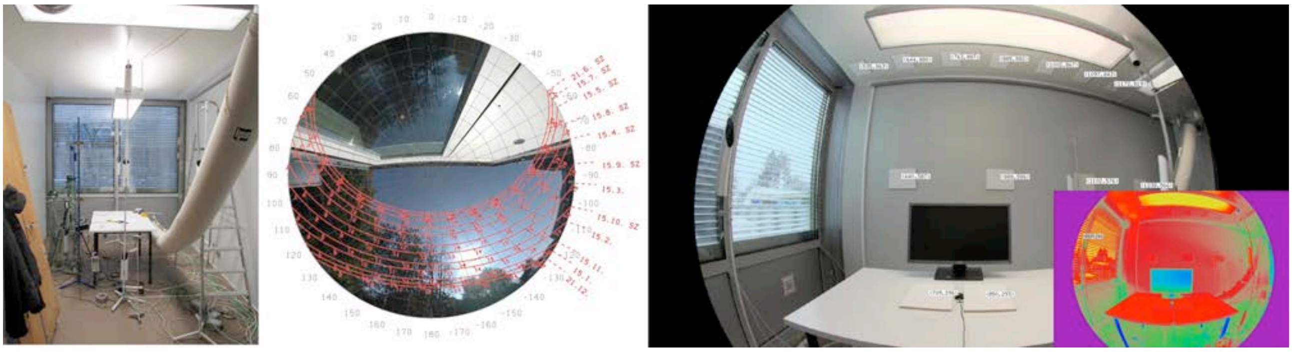

Figure: Mock-up to evaluate the lighting control scheme

Bartenbach already has realised several projects with a dynamic room illumination to obtain non-visual light effects. These projects were often situated in the health sector, as we see a great potential for HCL in this area. Furthermore, Bartenbach has completed projects with dynamic lighting for offices, industries, malls and shops as well as hotel rooms.

In the refurbishment of Bartenbach's R&D department (see below) as much daylight as possible is integrated by controlling the artificial light sensor-regulated (motion and daylight sensors). The CCT and the levels of illumination in the building depend on the situation outside, aiming to create a dynamic lighting solution that is biologically and energetically efficient. The psychophysiological and cognitive effects will be investigated in a long-term study.

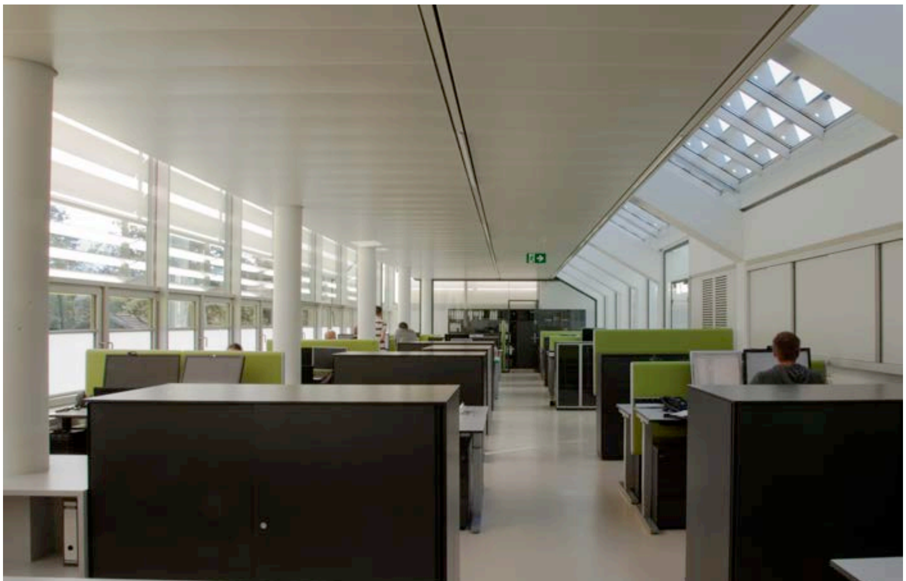

Figure: Dynamic lighting installation & integration of daylight in Bartenbach's recently refurbished R&D department

To make daylight solutions more affordable and accessible to the market, design tools (building simulation tools) are necessary. As an example, DALEC (Day- and Artificial Light with Energy Calculation) is an online concept evaluation tool for architects, building engineers, lighting designers and building owners. Although easy to use and short calculation times, the software accounts for the complex thermal and light processes in buildings and allows a simple evaluation of heating, cooling and electric lighting loads. Location and orientation of the facade, climate data, thermal and photometric properties of the room, different shading and electric lighting systems are taken into account in the calculation.

Not only energy, but also user behaviour is considered (e.g. in terms of overheating and glare protection) and visual and thermal comfort is evaluated. This innovative, holistic approach facilitates and accelerates the design of sustainable and energy-efficient buildings for new structures as well as for refurbishments. The energetic optimization of façade and electric lighting solutions is highly simplified, enabling building design with reduced energy demands.

The motivation behind the development of DALEC is to simplify the handling of the complexity coming along with the interaction of the thermal and lighting energy performance aspects. Furthermore, the simulation time must be less than a few seconds to allow optimizations of different façade situations. To realize that, the sophisticated lighting simulation components are pre-calculated for the most common room setups. As an example the daylight module is responsible for the calculation of the annual daylighting levels of the analysed room. An adapted and simplified daylight coefficient approach is used, which has been derived from the daylight coefficient model for dynamic daylighting simulations. To allow the usage of complex fenestration systems and to enable an efficient pre-calculation of the factors, the “Three-Phase Method” based on the validated simulation software RADIANCE is used.

Figure: DALEC user interface

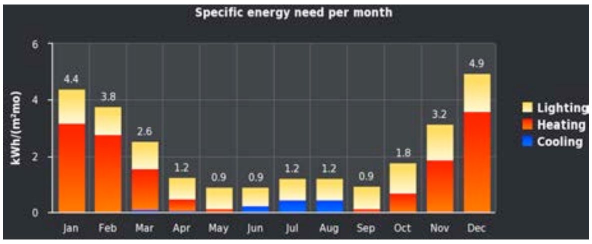

Figure: ***Resulting monthly energy needs for lighting, heating and cooling***

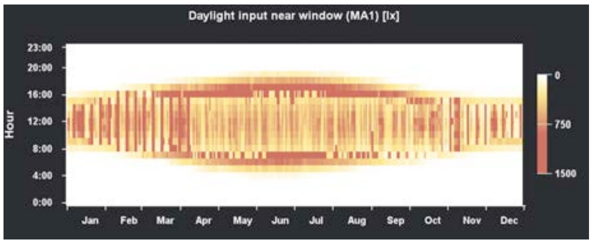

Figure: ***Annual chart showing the availability of daylight at the workplane next to the façade***

With this approach no simulation expertise is necessary for the tool user and calculation times are very fast. This allows optimisations of the façade settings, the artificial lighting installation and the thermal parameters of a building in an early design phase. It is not intended that DALEC replaces the existing, sophisticated energy and lighting simulation tools, but it will allow an accurate estimation of the influence of different façade setups on the electric lighting installation and different control strategies.

References

CIE x027:2004: Proceedings of the CIE Symposium 2004 on Light and Health: Non-Visual Effects, 30 Sep. - 2 Oct. 2004, Vienna, Austria.

CIE x030:2006: Proceedings of the ISCC/CIE Expert Symposium 2006 "75 Years of the CIE Standard Colorimetric Observer", 16-17 May 2006, NRC, Ottawa, Ontario, Canada.

ATKearney (2013). Humancentric Lighting: Going beyond Energy Efficiency – Market Study. URL: http://www.zvei.org/Verband/Publikationen/Seiten/Market-Study-Human-Centric-Lighting.aspx

Cajochen C, Münch M, Kobialka S, Kräuchi K, Steiner R, Oelhafen P, Orgül S, Wirz-Justice A (2005). High Sensitivity of Human Melatonin, Alertness, Thermoregulation, and Heart Rate to Short Wavelength Light. The Journal of Clinical Endocrinology & Metabolism 90(3): 1311-1316.

Lockley S, Evans EE, Scheer FAJL, Brainard G, Czeisler C, Aeschbach D (2006). Short-Wavelength Sensitivity for the Direct Effects of Light on Alertness, Vigilance, and the Waking Electroence-phalogram in Humans. Sleep 29:161-168.

Roenneberg T, Merrow M (2016). The circadian clock and human health. Current Biology 26:R432-443.

Canazei M, Dehoff P, Staggl S, Pohl W (2013). Effects of dynamic ambient lighting on female permanent morning shift workers. Lighting Research and Technology. doi: 10.1177/1477153513475914

Canazei M, Laner M, Staggl S, Pohl W, Ragazzi P, Magatti D, Martinelli E, Di Trapani P (2015). Room- and illumination-related effects of an artificial skylight. Lighting Research and Technology. doi: 10.1177/1477153515577852.

Canazei M, Bliem H, Pohl W, Weiss E (2016). Acute effects of different light spectra on simulated night shift work without circadian alignment. Chronobiology International (submitted).

Canazei M (2013b). Behavioural, mood-related and user-centred impacts of a 24 hr lighting scheme in a puerperal ward. Conference-Proceedings FNL-27 Symposium “Light and Health”, Berlin.

VisErgyControl (2014-2017). Integrale Tages- und Kunstlichtsteuerung für hohen visuellen und melanopischen Komfort bei hoher Primärenergieeffizienz. FFG-Projekt; Programm: Energie der Zukunft (Projektnummer: 845192).

Werner, M., Geisler-Moroder, D., Ebert, O., Bauer, C., Müller, R., Junghans, B., & Weitlaner, R. (2014). DALEC – Day- and Artificial Light with Energy Calculation - Konzeptanalysetool für ganzheitliche Lichtplanung. In Licht 2014. Den Haag.

www.dalec.net

Acknowledgement:

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 314461.