Sustainable Lighting for High-Rise Buildings: Lighting Solutions for High-Rise Buildings in the Context of Sustainability

Jonas J. Becker[1]

Master degree of Architecture
Hoshschule Ostwestfalen-Lippe
Germany
djonas.becker@posteo.org

Abstract
As awareness about Human Centric Lighting rises sustainable lighting concepts in high-rise architecture are more and more considered. Health and wellbeing are terms that become an essential part in light planning. The question is if there are sustainable solutions to improve this problem and if so how to implement them in the lighting planning of a modern high-rise building properly? And is there potential for improvement in sustainability of lighting solutions when it comes to working or living conditions? Two main sources of light are looked at: Daylight and artificial lighting. In the case of a modern high-rise building the lighting design necessarily consists of them both. However, the conclusions of the researches looked at in this paper show that it is of utmost importance of how this technology is applied. My findings show that melanopic effective lighting has the power to coordinate our circadian rhythms. Lighting solutions for daytime can positively influence our circadian rhythm by the consideration of natural light in project planning as well as the use of intelligent artificial lighting solutions such as the ones done research on.

***Keywords*: sustainable lighting, human centric lighting, high rise building**

I. INTRODUCTION

When it comes to light planning there are three aspects to be considered: According to pioneer lighting planner Richard Kelly artificial light can appear in three different forms: Ambient Luminescence, Focal glow and Play of brilliants.[2] The former two fulfil rather functional aspects whereas the third one can stimulate our eyes positively.

Modern high-rise buildings are usually suffering from a big inner space of the floor plan that is not lit by daylight and must be illuminated by artificial light. Natural light just doesn't reach far enough into the layout of the building. In the following paper, I am going to give examples about approaches to get as much daylight inside the building as possible as well as examples of layouts that are concentrating more on solutions using artificial lighting.

First my definition of sustainability needs to be defined in this paper with respect to the topic looked at. Sustainability as a holistic approach that includes optimised workflows of the building's users are considered when it comes to lighting. It covers the obvious aspects of energy consumption, invest and maintenance costs and moreover the aspect of working conditions in respect of health, wellbeing, efficiency and other aspects. The first two points concerning energy and costs are answered really quick and so I am not covering them in detail. LED (Light Emitting Diodes) is the solution of choice that quickly answers those questions almost entirely.

A state of the art building should provide the same functional support to the user no matter be it day or night. Performing work tasks by making use of artificial lighting is commonly seen in modern workspaces today.

[2] Neumann, Dietrich, Robert A. M. Stern, und D. Michelle Addington. 2010. The Structure of Light: Richard Kelly and the Illumination of Modern Architecture. New Haven: Yale Univ Pr.

Currently there are major changes in demands and requirements when it comes to lighting design of high-rise buildings. Reducing the operational costs and in order to comply with exacerbated energy saving laws drives this development even faster. This allows and requires the implementation of evolved technologies that are ready to be implemented in projects.

The case studies show the potential of improvement in sustainability in high-rise buildings when it comes to lighting solutions. Both cases show a high degree of implementation of natural daylight with two different approaches. A possible solution that put the human factor in centre when it comes to situations that need to be supported with artificial light is introduced in these researches.

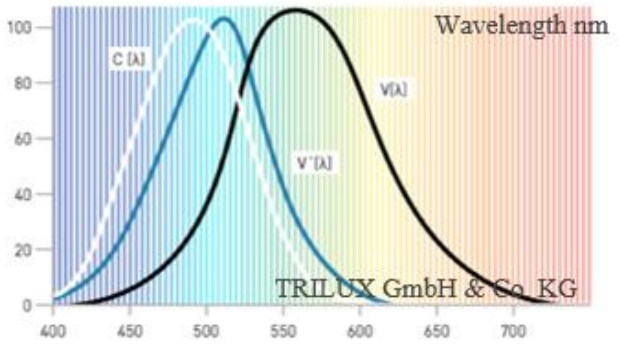
II. Melanopic Sensitive Lighting

Melanopsin is a photopigment in ganglion cells that was discovered by G. Foster, Ignacio Provencio + partners and published only quite recently in the year 2007. Ganglion cells in combination with its 'agent' melanopsin on the retina of the human and animal eye are light-sensitive and jointly responsible for suppressing the release of the hormone melatonin from the pineal gland. The human circadian rhythm is influenced by the light that is emitted to those cells. Absence of light is registered by the photosensitive ganglion cells that activate the hormone melatonin which causes fatigue. Presence of light however prevents the hormone from being produced and keeps us awake.

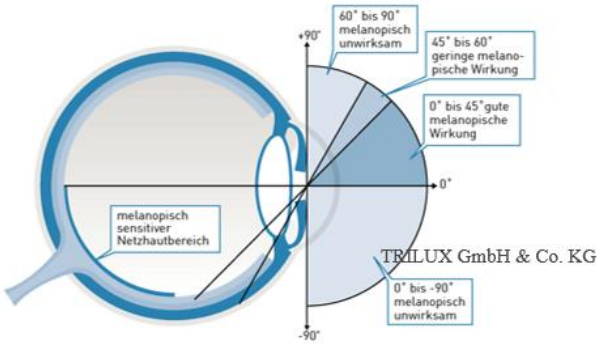
Since the first discovering and developing of artificial light and especially electrical lighting this effect has been used to bend the natural day-night rhythm of humans in order to control primary work life starting from the age of industrialisation.

The potential when it comes to artificial lighting today is to influence and optimise this control of the day-night rhythm further by using the knowledge that is been accumulated still today about what frequencies of the visual light wavelengths influence the melanopsin and how exactly. Artificial light can and is tuned very easily in its wavelengths without even been consciously noticed be the user. The effect takes place subconsciously and is thereby to be used wisely and to be seen as a slight medical intervention that should be accepted in advance by the user when used at the workplace. This to me is a topic to be looked at very differentiated and carefully as the effect can be strong to the user whether it be positively or negatively. The circadian rhythm is influenced and optimised/'tuned' subconsciously from the outside.

Transferred to the question of sustainable lighting solutions in high-rises the use of melanopic optimised lighting solutions can be a very effective tool to further strengthen the sustainability in work-processes by making the work outcome more successful through the lighting solution applied. This knowledge can help to gain an understanding for the melanopic effectivity of different wavelengths of visible light. Findings in studies show that blue (wavelength not colour) enriched light (melanopic weighted illuminance levels) can improve concentration, performance and reduce errors.[3] Dependent on the chronotype of each individual the modulation in wavelength of artificial lighting throughout the day can help each of us to learn or work efficiently and as important to recreate effectively. Most people need support to get awake in the morning and have trouble to calm down in the evening. Therefore, a support by blue wavelength in the morning and a relaxing impulse by slightly longer (reddish) wavelength (not melanopic effective) in the evening can be reasonable. However, it should be respected that other chronotypes exists what makes a highly individual treatment necessary.



Spectral brightness sensitivity
V(λ) Daylight vision
V'(λ) Night vision
C(λ) melanopic effect function



Melanopic effectiveness of light is dependent on the wave angle of light and the size of light-source

III. Artificial Sun CoeLux Research Hochschule Ostwestfalen-Lippe

Can advanced lighting-technology influence perception in a work environment? And how if so? This question was raised in the students' research project of Hochschule Ostwestfalen-Lippe. The product done research on is the artificial sun of Italian lighting company CoeLux®. In this

[3] Light and education - Non-visual effects on academic performance (research TU Munich)

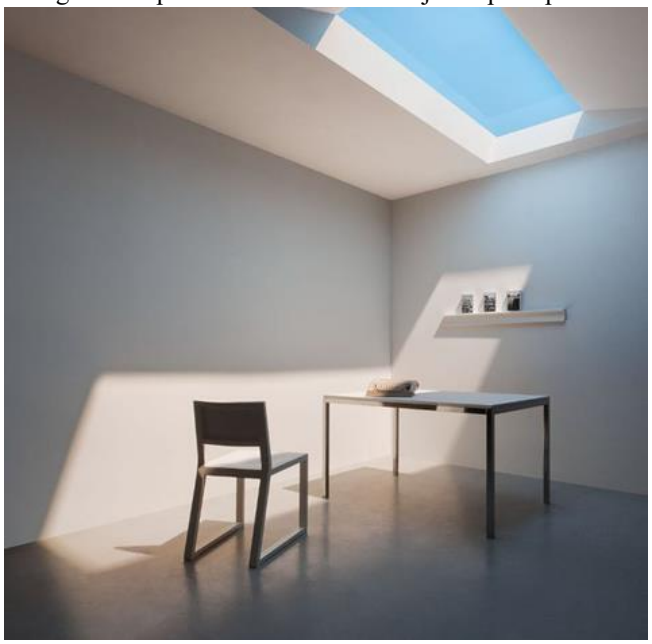
study, a perceptional comparison of a room with natural lighting by a skylight/roof window and a room equipped with the artificial sun was conducted. It should be noted that natural lighting in Germany differs very much throughout the year. Blue sky is a 'rare plant' in the northern part of Germany during wintertime. As this research was conducted in the winter term the predominant sky color was light to dark grey without direct sunlight. Whereas the artificial sun provides clear blue sky and sunshine every day.

In this research study participants had to fulfil certain tasks in each of the rooms and answer a questionnaire about their perception of the room and its light in regard to perform the task given afterwards.

Conclusions of the study are as follows:

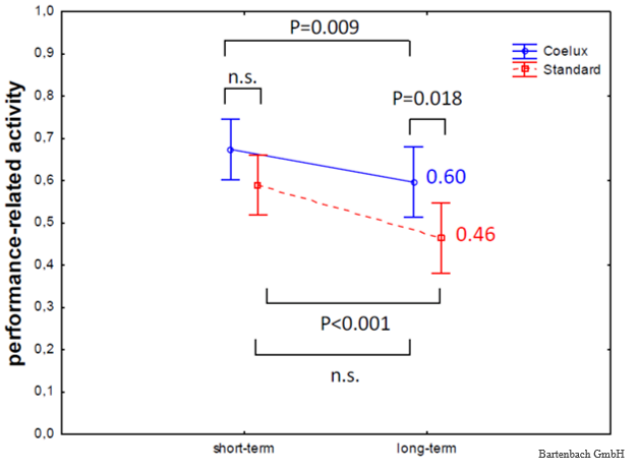
"Regarding to the perception in both test rooms (Light-lab with artificial sunlight and Pro-Ebene with natural light), the results of the semantic differential show that there were no exceptional deviations. We come to the conclusion that both rooms were perceived quite similar. Most of the subjects stated to be satisfied with the light conditions in both rooms.

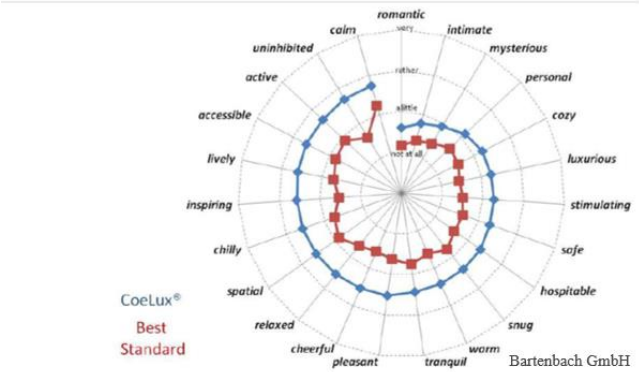
Moreover, as mentioned before, we can assume through the data we collected and evaluated, that the artificial sunlight has a positive effect on the subjects' perception."[4]



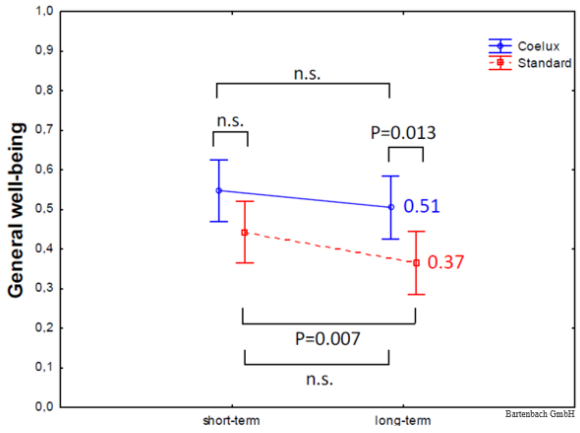
IV. Report on comfort and wellbeing measurement. Bartenbach

The research done by Bartenbach GmbH simulated a different scenario: One room was equipped with the artificial sun product the other one with a standard lighting system. In terms of perceived ambient quality, the participants of the study associated the room with the artificial light solution as more positive compared to the room with standard artificial lighting.[5] Psycho-Physiological parameters such as perceived mood state, perceived anxiety, perceived room environment, perceived stress state and sustained attention all turned out better with the artificial sun solution over the standard one.





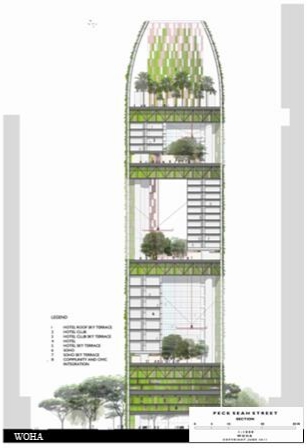
Lighting technology like this one can easily be integrated into room-layouts without natural daylight. Assuming that these rooms often appear in high-rise building layouts these kinds of solutions could be a significant improvement of the users' perception in rooms without windows.



[4] CoeLux® Artificial Sun Research Hochschule Ostwestfalen-Lippe, Prof. Mary-Anne Kyriakou

[5] Report on comfort and wellbeing measurement. Bartenbach GmbH

V. OASIA DOWNTOWN HOTEL SINGAPORE



One of the most consequently realized high-rise projects in Southeast Asia when it comes to innovative green design is the WOHA's most recent tower building in Downtown Singapore. Singaporean Architects Wong Mun Summ and Richard Hassell created this one of a kind be-tween 2011 and 2016 as the latest of their approaches to improve the climate in densely poppulated areas.

Singapore downtown area suffers from the heat island effect quite badly as glass facade high-rise buildings seem to compete in reflecting the IR-radiation down to the narrow streets with their mirror like sun protecting glasses. In combination with the cities dense urban planning this perfectly represents the unsustainable solution to me. Unsustainability in the form of total ego-centrism in reaching the goal of a working and 'representative' looking high-rise building. It is not considering the effects it has on the surrounding or even worse hazards the consequences of it by turning its surrounding in unlivable spaces. Moreover, high amounts of electrical energy are needed to cool down the rooms behind the glass facades.

WOHA's green tower building however takes a different approach that polarizes when it comes to light planning. The merge of daylight and artificial light is put into a different perspective with this project as a result of the green design. Two main aspects can be determined in WOHA's 'green' approach. First the consequent external shading and secondly the creation of a livelihood for green on the building.

Natural daylight in the open-air areas, high amount of external shading by the plants and it's grids and artificial lighting inside. In addition, it needs to be mentioned that the creepers and other plants on the facade create a kind of vertical garden and give a habitat to insects of different sort. This influences the environment around the tower positively for animals as well as for human beings as the plants clean and cool down the air around the building and have a non-reflecting surface.[6]

The building opens itself to the inside in the form of several story high carves into it on 4 different levels. Direct sunlight appears less strong in those angels preventing severe heating of the inside of the building.

VI. HSBC BUILDING HONG KONG

In 2004, the HSBC building in Hong Kong designed by Sir Norman Foster became part of the Victoria Harbour Lighting Plan. This building is one of a kind when it comes to its spatial structure. Open working spaces throughout the whole floors surrounding an all story high atrium that also brings daylight to the inside. This building demonstrates a highly-developed lighting planning of daylight on the one hand as well as artificial light on the other. This architecture is considering light from the beginning of its planning on and can be seen as a unique example of a solution of illuminating the inner layout of a high-rise building without the use of advanced artificial lighting solutions to solve the problem but with the use of natural daylight instead. All made possible by the advanced building construction by Forster + Partners.

There are two aspects I would like to point out about this project concerning its lighting concept. First there is the completely modernized interior lighting and secondly there is the newly applied exterior lighting concept. This two concepts kind of interfere with each other however in a way that destroys the original idea of Sir Norman Fosters 'modern working factory' as to be a building that turns its inside to the outside during nighttime by the means of

[6] Green Walls in High-Rise Buildings: An output of the CTBUH Sustainability

illumination.[7] Originally, it's lighting concept was rather reduced putting the constructive design of the building and its technical impression in focus. Through the glass facade its huge open space working floors became visible to the outside during nighttime. the external bearing structure was enlightened by a slightly warmer white light color to emphasize it as well. Today though the building became a proper rainbow of colors compared to its former life. The external structures are illuminated in changing color themes making it appear like a Christmas tree to me. Moreover, there is an enormous led-screen attached to the upper facade completely destroying the translucency of it. The building became literally a part of a light show rather than keeping its identity of a transparent skyscraper. This to me is the opposite of sustainable light planning as the Hong Kong Victoria Harbor light show appears to be a prime example of light pollution and waste of energy. Light shows can be very artistic, unique and even technological smart as many events around the world such as for example SuperLux Smart Light Art, Design and Architecture for Cities proof.

VII. Conclusion

Natural daylight still is the only visible electromagnetic radiation that consists of the full wave-lengths in the visible color spectrum. It can be seen as the only 100% true sustainable lighting there is. The positive influence it has on us human beings is not totally replaceable by any mod-ern artificial lighting solution. But there are new technologies getting ready right now which improve the widely used common approaches. Modern high-rise architecture especially in densely populated cities is predestined for these changes as the users' perception in windowless room layouts could highly benefit from lighting solutions that simulate natural daylight much more accurately and cover also subconscious perception rather than just the functional aspect of sufficient brightness that is still predominant in light planning.

Light has the power to coordinate our circadian rhythms.[8] Artificial light during the night is a disturbance of our biological clock. But if we need lighting solutions for daytime we can positively influence our circadian rhythm by the consideration of natural light in project plan-ning as well as the use of intelligent artificial lighting solutions. [9] In the progress of my research paper I found a significant potential to improve working and living conditions in modern high-rise buildings as a sustainable approach. Disadvantages of artificial lighting solutions over natural light that may be partly responsible for diseases such as sick building syndromes or depressive moods may be reduced by these measures as well I presume. Moreover, lighting should always be considered in a holistic approach. Meaning the light source is only one requirement for visible illumination. The surface the light reflects from and by this becomes visible by our human eye is evenly as important and thereby to be considered in the overall interior and in case of dense settlements such as high-rises in exterior planning as well. An early implementation of lighting planning and general interior planning in the architectural design is from utmost importance to enable a sustainable lighting planning for every spatial design imaginable.

The answer to my initial question if there is potential of improvement in sustainability in high-rise buildings when it comes to lighting solutions can be answered with a crystal-clear yes there are plenty of options as the examples of projects and researches discussed in my paper show. Light planning becomes a boost in importance as technological possibilities and sustainable demand as well as research evolves significantly right today.

[7] International Light Symposium SuperLux - Smart Light Art, Design & Architecture for Cities; Speech from 7. December 2016 at Technical University of Munich

[8] Lighting Design for Health, Wellbeing and Quality of Light, A Holistic Approach on Human Centric Lighting; A White Paper from the IALD European Regulatory Affairs Working Group

[9] CoeLux® Artificial Sun Research Hochschule Ostwestfalen-Lippe, Prof. Mary-Anne Kyriakou & Report on comfort and wellbeing measurement. Bartenbach GmbH

References

[1] CoeLux® Artificial Sun Research Hochschule Ostwestfalen-Lippe, Prof. Mary-Anne Kyriakou
[2] Report on comfort and wellbeing measurement. Bartenbach GmbH
[3] International Light Symposium SuperLux - Smart Light Art, Design & Architecture for Cities; Speech from 7. December 2016 at Technical University of Munich
[4] Green Walls in High-Rise Buildings: An output of the CTBUH Sustainability"Lighting as an In-tegral Part of Architecture" College Art Journal, Vol. 12, No. 1, (Autumn, 1952), pp. 24-30 Published by: College Art Association
[5] Neumann, Dietrich, Robert A. M. Stern, und D. Michelle Addington. 2010. The Structure of Light: Richard Kelly and the Illumination of Modern Architecture. New Haven: Yale Univ Pr.
[6] LICHT2016 Proceedings: Lighting is an object of research in many disciplines: as a factor in energy research, as component of intelligent smart home systems in IT technology, in optics and photonics, and as a design element in architecture. All these aspects have been addressed during the conference "LICHT 2016"Beleuchtungspraxis, TRILUX GmbH & Co. KG
[7] Lighting Design for Health, Wellbeing and Quality of Light, A Holistic Approach on Human Centric Lighting; A White Paper from the IALD European Regulatory Affairs Working Group
[8] Light and education - Non-visual effects on academic performance (research TU Munich)nWord Count: 3.241