Inaugural lecture
Prof.Dr.-Ing.habil.
Alexander Rosemann
March 6, 2015

/ Department of the Built Environment

Technische Universiteit
Eindhoven
University of Technology

Balancing Light

Where innovation starts

Inaugural lecture Prof.Dr.-Ing.habil. Alexander Rosemann

Balancing Light

Presented on March 6, 2015
at Eindhoven University of Technology

Introduction

Mijnheer de Rector Magnificus, geachte collega's, beste familie en vrienden, zeer gewaardeerde toehoorders,

It is a great honor for me to stand here in front of you and present my inaugural lecture. Inaugural lectures give new professors a chance to introduce their vision of their field of work to the university community, to colleagues outside the campus and to friends and family. For this reason I am grateful that I have this opportunity today and appreciate you all taking the time to attend this event.

I have been appointed full professor and chairholder of "Building Lighting" effective from April 2014, a bit less than a year ago. 5 months earlier, in December 2013, the United Nations General Assembly proclaimed the year 2015 as the "International Year of Light and Light-based Technologies". You can imagine that I feel also very proud that my inaugural lecture has been scheduled in this very year.

While the 20th century was dominated by the electron, the 21st century is seen as the century of the photon, a guiding subject of the research aspirations of my own doctoral supervisor Prof.Dr.rer.nat. Heinrich Kaase. The link between lighting technology, optical technologies, information technologies and electronics is still valid today and certainly also applies to building lighting.

Societal Challenges

The European Union has identified societal challenges that we are and will be facing in the years to come. These challenges include health and wellbeing and efficient energy as well as innovative and secure societies [1]. Answers to these challenges are sought from industry and universities. Universities are expected to contribute to the solutions through research and education. The next generations of scientists, engineers and other professionals will take on the tasks of tackling these challenges to the overall benefit of society. Being successful in this undertaking provides many opportunities for discovering and applying the economic potential of innovative ideas leading to exciting career paths for those who participate in this.

Eindhoven University of Technology has already reacted to the societal challenges by identifying three main strategic areas for research: Energy, Health and Mobility. The overall strategy of the university addresses these societal challenges and everyone is encouraged to contribute towards solutions.
Considering the strategies and the tasks defined by the societal challenges, I see three areas that relate to them and that define the scope of the research interests of the Building Lighting group:

- Light & Energy
- Light & Environment, and
- Light & Health

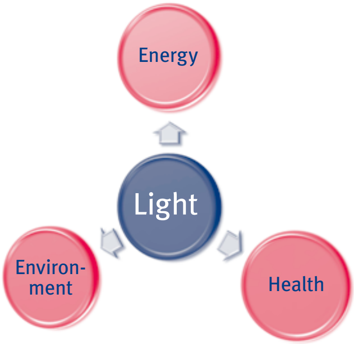

Figure 1

Societal Challenges for the field of lighting

Focusing on one area alone will not lead to sustainable solutions to the societal challenges. The overall aim must be to find an optimum within these three areas. In the following sections of my lecture, I will investigate these three sectors individually. This does not mean that I disregard the importance of the other two; it is intended to define the challenges in each area to outline the overall complexity of finding solutions that fulfill the needs of all three aspects, energy, environment and health. I often compare this with the attempt to balance an object, for instance a book, with three fingers. If any of the three sustaining pillars is insufficient, the book will slide down indicating the result of an imbalanced solution.

Overview of Speech

In my speech I would like to outline these three pillars and how they relate to research in the overall field of building physics and services. What are the related challenges and opportunities through major developments? After developing this train of thought, I want to close with a concrete research example at the Building Lighting group.

Light & Energy

The limited amount of the resources in general and energy carriers in particular that are available to us compel us to use this energy responsibly. The Strategic Area Energy of the TU/e clusters the field into the following 5 topics:

- Generation,
- Distribution,
- Storage,
- Conversion, and
- End use

Building Lighting fits in to the last topic. Energy-efficient solutions for Building Lighting can have a significant impact on the overall electrical energy consumption in the building sector. Advancing this research area of Building Lighting is directly related to the societal challenges Europe faces and will remain a priority for the years to come.

The energy efficiency of a lighting system is determined by a series of measures. Starting from the generation of light to the point of end delivery, one can cluster the contributing modules in a similar manner as has been done for the overall Strategic Area Energy:

- Electric Lighting System (Generation, Distribution),
- Daylight System ("regenerative Generation", Distribution),
- Materials (Distribution, Module efficiency), and
- Control System (End use).

Electric Lighting System

Industrial research and development efforts have increased the efficiency of light sources. The luminous efficacy of lamps has come a long way since the invention of the incandescent lamp, the patent by Thomas Alva Edison [2] and the wide adaptation of this electrical light source during the beginning of the 20th century. The measure of a lamp's energy efficiency is the luminous efficacy. It relates the generated luminous flux to the electrical power draw by the lamp. While incandescent lamps typically deliver 10 to 12 lm/W, modern lamp types can reach 10 times more than that.

It is due to the rapid development of LED lighting systems that I refrain from providing a typical number for lamps based on electroluminescence. The invention of efficient blue LEDs enabled the development of white LED lamps that are both energy-efficient and environmentally friendly. The inventors of the blue LEDs, Isamu Akasaki, Hiroshi Amano and Shuji Nakamura, were awarded the Nobel prize in physics last year. This underlines the importance of their invention and honors the impact that their invention has already had on the lighting sector. In their publications on the 2014 Nobel prize [3] [4], the Royal Swedish Academy of Sciences points out that white LEDs currently reach up to 300 lm/W.

The efficiency of electric lighting systems is also impacted by the ballast or driver technology. In addition to their base functions of starting and operating lamps, ballasts also provide an interface to light management systems to receive commands of sorts that dim or alter the light output of the lamp. This third function becomes more and more important when including the lighting system in a light control system or a building management system. The efficiency of lamp ballast combinations is described by the system's luminous efficacy η_S which considers the electrical power draw of the ballast in addition to the power draw of the light source itself.

Daylight Harvesting

Apart from the recent – in relative terms – electrical lamp technology, the oldest light source that we experience here on Earth also contributes to the energy-

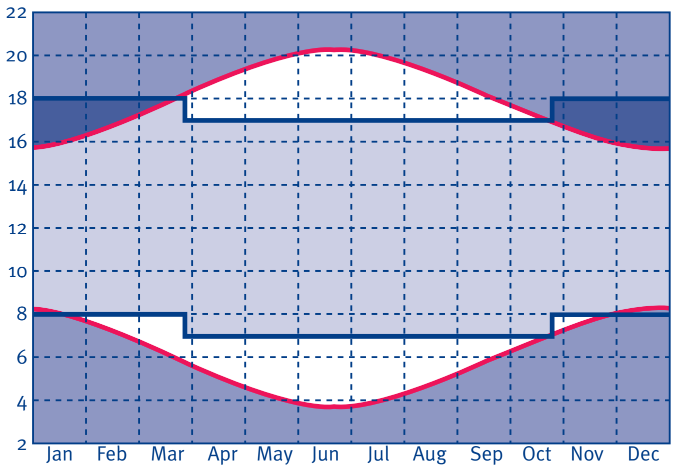

Figure 2

Daylight availability in Eindhoven during working hours from 8 am to 6 pm efficiency in building lighting: the sun. The natural daylight is available for free and we can use it to offset electrical lighting whenever a sufficient amount of daylight can be made available in building interiors. Throughout the year, daylight is available during most of the working hours (Figure 2).

Daylight harvesting can be obtained in a variety of ways. The International Energy Agency has published a source book on Daylight in Buildings that provides an overview of daylight systems [5]. There are systems for the roof of a building such as skylights and rooftop monitors as well as systems for the vertical façade. Daylight can be re-directed to the ceiling for further distribution in the room via reflection (e.g. via light shelves or redirecting blinds). Daylight can also be transported deeper into the room and coupled out closer to the core of the building via transport systems such as anidolic ceilings [6] or hollow light guide systems [7]. Such systems can be static or moving to track the sun (via heliostats).

From this brief and certainly not complete overview of different approaches towards daylight utilization in buildings, one can already see that the great number of different approaches caters to different needs in daylighting due to different geographical and meteorological conditions. The daylight harvesting must consider the location, orientation and typology of the building.

Calculations or simulations on the annual performance can then inform about the room potential and system potential with respect to daylight harvesting. Robust methodologies offer the designer a tool to select a daylight system suitable for the project.

Materials

Materials also impact the energy efficiency of a solution. Relevant optical characteristics of a material used in a lighting system need to be considered in the design of components and modules. The conventional luminaire design includes the utilization of suitable materials in order to distribute the light generated by the light source(s) in the desired fashion. The material characteristics of the interior surfaces determine the luminance distribution for a given lighting situation and also impact the illuminance from interreflections on areas where visual tasks are being performed. The third area where material characteristics are important to consider is the design of daylight systems.

Unlike luminaires and interior room surfaces, daylight systems connect the building interior to the exterior situation. This requires the consideration of additional quantities on the module level that go beyond the visual characteristics such as the luminous transmittance and reflectance or the spatial distribution of the luminance coefficient. Quantities affecting the thermal situation inside the building are of equal importance, such as the solar gain factor and the U-value to name but two examples.

Control System

The control systems can be as simple as a one-sensor system for switching the electric lighting on and off depending on the requirements inside the room. A very common sensor type is the occupancy sensor that switches the light off when no occupant is detected. Such lighting controls have been state of the art for a long time and are a minimum requirement in many building codes, e.g. the Canadian National Energy Code for Buildings (NECB) [8].

Energy savings for building lighting through daylight harvesting can only be obtained when the electrical lighting is controlled in response to the daylight availability inside a space at any given time. Open-loop and closed-loop strategies for efficient daylight harvesting are explored.

Optimizing a control system requires more sophisticated control strategies including more actuators and sensors as well as novel algorithms. The benefits of daylight harvesting can be increased by also controlling the daylight system, e.g. the angle of the blinds. Advanced controls systems need to take the entire interior situation into account and respond to the requirements of other end uses such as heating and cooling. Similar to the selection of a suitable daylight system, a successful control strategy needs to consider the local conditions.

Conclusion Light & Energy

Energy-efficient lighting systems need to look at the optimized utilization of electrical lighting systems, suitable daylight systems and a means to control these systems by the use of adequate controls and control strategies [9]. The energy savings depend on the combination of the room potential and the system potential [10]. The energy savings from a combined electrical and daylighting system depends on the geographical and meteorological situation.

Recommendations for good lighting design must therefore consider all aspects relevant to the energy efficiency of a lighting system.

Light & Environment

The second pillar "Light & Environment" addresses the visual environment that users experience. Light has an impact on people. Incorrectly illuminated environments disturb them whereas well-designed lighting scenarios can provide an ambience that supports the function of the space and has an impact on the visual performance of the occupants.

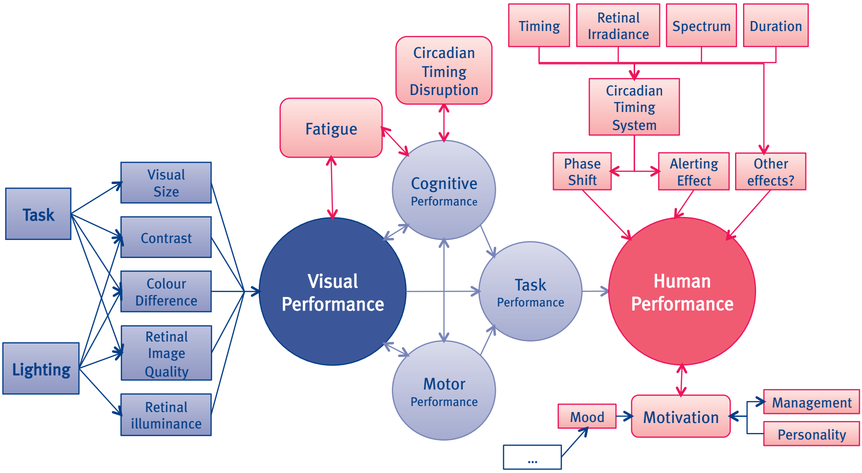

Figure 3

Excerpt of the Conceptual framework for visual and human performance after Boyce [11]

Prof.Dr. Peter Boyce has developed a conceptual framework for visual and human performance [11]. A large excerpt of this framework that addresses is shown in Figure 3. The human performance is linked to the visual performance via the task cognitive and motor performances. The lighting situation impacts the visual environment via quantities like contrast, color difference, retinal image quality and retinal illuminance. Via the route shown in the framework, the lighting impacts the overall human performance, thus making lighting an important aspect for the design of efficient work spaces.

Improving an occupant's visual experience can be achieved by creating a lighting situation that enhances the occupant's satisfaction. This means that the occupant is not getting disturbed or discomforted by the lighting situation at any time.

Occupants have a general preference for daylight. It provides physiological as well as psychological benefits in addition to the energetic advantages that were discussed in the previous chapter.

The spectral composition of daylight provides ideal color rendering. Often we bring products that we intend to purchase such as clothes close to the window in order to evaluate their color appearance. We trust our judgment when we illuminate our environment with daylight.

The dynamics of daylight play an important role to our well-being inside a building. We get feedback on what is happening outside via the variations in the daylight contribution. This provides information on weather and time of day.

A psychological aspect of daylight use and its impact on enhancing the visual experience is creating a view to the outside. The access to a window with an outside view shows positive effects on satisfaction with the lighting and better indoor environments have a positive impact on job satisfaction [12]. "Views to the outside" could also be provided by Virtual Natural Lighting Solutions (VNLS). These are systems that provide artificial lighting as well as a realistic outside view with properties comparable to those of real windows and skylights [13].

In the absence of daylight and in cases where the daylight contribution is not sufficient for acceptable illumination, electric lighting needs to provide a visual ambience that is acceptable to the user. Rather than static lighting as we experience it in most buildings, the aim must be to create dynamics similar to the ones from daylight to achieve similar benefits. This requires a good understanding of the factors that determine the visual performance and the human performance according to the framework by Boyce.

Factors limiting the visual performance may or may not be noticed by the occupant. One example is the physiological and psychological impacts of glare. Physiological glare is defined as glare that limits our ability to perform a visual task. It is also called disability glare and may not necessarily be noticed by the occupant. Psychological glare is defined as the glare that occupants notice and that disturbs them. This type of glare is also referred to as discomfort glare.

The control system and strategy can also have disturbing effects on occupants. Imagine a scenario in which light emanating from a luminaire within the field of view is dimmed too quickly. This "sudden change" gets noticed and can potentially lead to a disturbance which takes away an occupant's focus from the task at hand. In a similar manner, a control system that too frequently changes the angles of the blinds can result in an annoyance to the user which reduces the concentration or cognitive performance.

The typical reaction to any disturbing impacts is to eliminate them. In the two different examples on glare and controls one would expect users to search for a solution if they regard the situation as "unbearable" or "unacceptable".

Recommendations for good lighting design must therefore consider all aspects relevant to creating a good visual environment.

Link to Light & Energy

Creating a visual environment will maintain user acceptance of the lighting system. Failure to do so may result in the user interfering with the system to re-commission or even "de-commission" it. This will then create a lighting situation that was not intended by the designer.

In relation to the energy efficiency, which requires a daylight dependent lighting control in order to achieve an energy-efficient lighting solution, a second boundary condition applies: the lighting solution has to be acceptable to the user, which may prompt the inclusion of daylight systems and their connection to the building management system as shown in Figure 4.

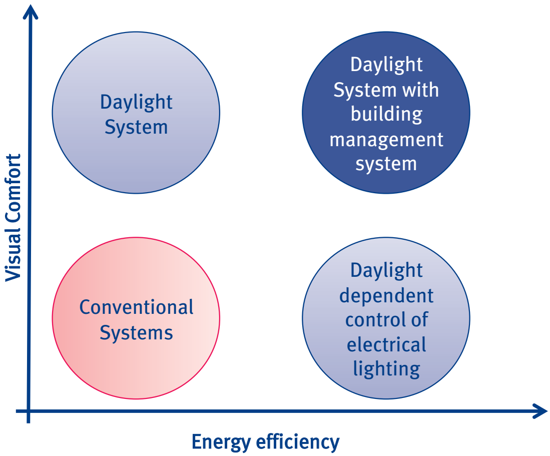

Figure 4

Synergies between energy efficiency and visual comfort after [9]

Light & Health

The third pillar addresses another field of lighting research that directly addresses benefits to humans. Radiation can have an impact on the health of humans. There are a number of effects caused by ultraviolet (UV), visible and infrared (IR) radiation and can be triggered via the skin or the eye.

The field of research “Light & Health” is relatively young and there are still many open questions. While the negative impacts of radiation on human health have been highlighted in the past, with the intention to dramatize, interdisciplinary discussions on the impact of lighting on health have recently been established [14].

There are too many effects to discuss them all in detail, ranging from the synthesis of pre-vitamin D_3 to seasonal affective disorder (SAD). For each effect, a spectral sensitivity curve has been or needs to be defined in order to quantify the impact of radiation. Rather than relating the effects to photometric terms, which themselves are related to the V(λ) curve (the sensitivity function of the human eye), different action spectra apply. That means, for instance, that instead of an illuminance, we

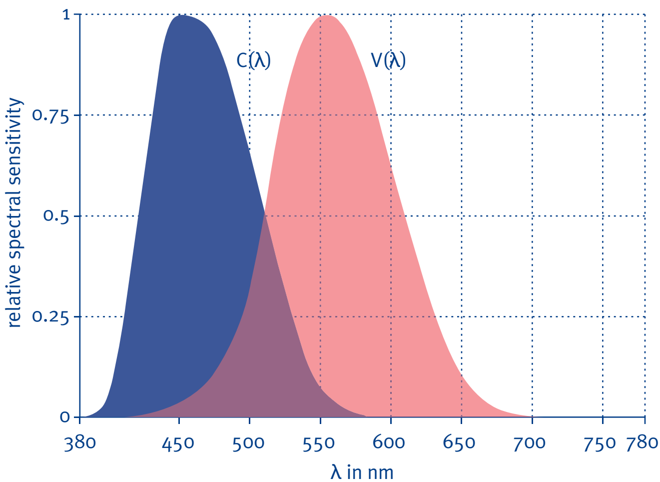

Figure 5

The sensitivity function of the human eye V(λ) and the circadian action spectrum C(λ) speak of an effective irradiance with respect to a given photobiological effect. While this may appear hair-splitting, the correct use of terminology based on a robust nomenclature is essential to describe the impact of luminous radiation on human health.

The difference in two relevant action spectra shown in Figure 5 emphasizes the importance for a clear nomenclature. While the eye sensitivity function V(λ) helps to evaluate visible radiation according to its visual impact, the circadian action spectrum C(λ) describes its non-visual effect with respect to melatonin suppression, something that is seen as an important component to control human circadian rhythm [15].

The knowledge of health impacts will inform and guide lighting research and the development of applications and devices. This requires the definition and subsequent standardization of

- action spectra,
- maximum effective doses to prevent negative impacts, and
- minimum effective doses to trigger health benefits.

One of many examples is the research into optimized technology for light therapy. Knowledge of the action spectra led to the development of a light cabin optimized for the needs of patients whereby the duration that they needed to spend in the cabin could be reduced and other, negative effects could be avoided [16].

Returning to the conceptual framework for visual and human performance shown in Figure 3, the health-related effects of visible radiation also impact visual and human performance. Apart from the health and wellbeing benefits for the workers themselves, good lighting also leads to better work performance (speed), fewer errors and rejects, better safety, fewer accidents and lower absenteeism [17].

Based on this, we can now develop a vision that shows up the overall potential of healthy lighting: for one employer the reduced cost of the aforementioned benefits indicate the economic feasibility of healthy lighting. While this is limited to an individual benefit analysis here, what if we expand this thought and apply it on a larger scale (e.g., a region or a country)? Even if we only consider the entirety of office-related workspaces, the potential societal benefit and economic impact of healthy lighting quickly ramps up, not only by the number of people impacted but it also in terms of initial positive secondary effects such as reduced (variable) healthcare costs.

With this vision as a guide, one can conclude that:

Recommendations for good lighting design must therefore consider all aspects relevant to creating a healthy luminous environment.

Link to the other pillars

Each of the three sections – Energy, Environment and Health – has resulted in a statement on the recommendations for good lighting. These statements are structured identically so that they can be combined to create an overall principle that relates to human needs and societal challenges.

Developing the figure on the connection between energy efficiency and visual comfort further, we can add a third axis to the graph that indicates the health benefit of lighting. Baseline scenarios and enhancements can be evaluated using such a scale. They can visualize alternative design options as they relate to each of these important pillars.

Integrated Approach in Building Physics and Services

The focus of this lecture is on Building Lighting but I want to recognize that lighting is not the only end use in the Built Environment. When speaking of optimization of lighting with respect to a goal, be it energy efficiency or health, I have not yet mentioned any boundary conditions that may apply. Conditions and parameters affecting the design of a building as a whole or spaces within a building are manifold and include the building archetype, technical specifications or recommendations from building codes or standards for common, good or best practice (see Figure 6). The expected operation of the building needs to be implemented via a suitable building management system applying a control strategy that allows the desired level of user interaction in order to achieve the design goal and user expectations. All these boundary conditions need to be addressed in an integrated manner within the different building design sections. For this, the impact of design decisions taken within one particular area on the other building services must not be ignored. Methodologies that inform the overall energy performance of buildings have been developed and are already being applied in many parts of the world. These methodologies need to be enhanced further to make them applicable for different situations and also to address not only the energetic performance of a building but also other parameters affecting the comfort of building occupants.

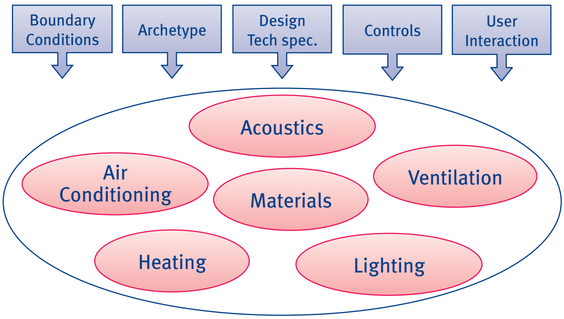

Figure 6

Selection of building design sections to be considered for integrated building design

Within this context, the field of Building Lighting can be split up in three major areas that impact the lighting situation in indoor environments (see Figure 7):

- the electric lighting situation,
- the daylight situation, and
- the room.

While the points electric lighting and daylighting are self-explanatory, the bullet “room” not only addresses the geometric measures and orientation of a particular space inside a building but also defines the intended use of the space and, subsequently, the requirements and recommendations that apply to the illumination of the space. Just as with the overview on the building end uses, the same set of outer impact factors applies.

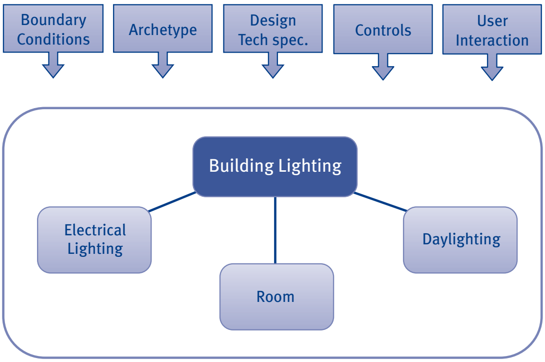

Figure 7

Main topics contributing to the building lighting situation

Challenges & Opportunities

All unanswered questions show up a set of challenges and therein lie opportunities. The term “challenge” can be interpreted in a multitude of different ways. According to the Merriam Webster Online dictionary one definition of the noun “challenge” is:

a difficult task or problem: something that is hard to do

I would like to relate this to the research where we also find many challenges. Research challenges can also arise from particular developments that have the potential to impact our daily life in both a positive or negative manner. I have already mentioned the societal challenges published by the European Union. The definition also mentions the word “problem”. Out of context, the word “problem” always has a negative tone to it. I like to understand the word “problem” more as a pressing challenge where a solution needs to be found. I would like to apply the definition in the terminology and focus on identifying challenges and turn them into research opportunities.

Guiding Principles

There are many research questions that can be identified. Can we put them in order or can we sort them? Can we pre-evaluate the research questions that we identify?

The attention of research (and research funding) is increasingly focusing on the relevance of its expected outcome to society. It is essential to check the potential of a research opportunity in this regard. What is the benefit of the outcome and to what extent does it impact society if it is applied? This to me sounds very much like a potential analysis in marketing. Two basic pieces of information are essential to quickly qualify the potential:

- the magnitude of the benefit, and
- the size of the market segment to which the result can be applied.

The relevance of a research challenge to society can be determined by the interest of industry in particular research opportunities. Public-private partnerships show that the potential outcome of a research activity is important as it is likely to serve a need associated with a certain market or market segment.

This leads to the overall approach of market transformation. In general terms, research that is relevant to society has the potential to improve the way we live or work. Subsequently, it will change things or transform the market. Within my former affiliation in the electric utility business, we used the market transformation curve as a guiding principle in pursuit of our goals. We identified a list of opportunities and checked their potential within the context of market transformation by identifying the technical potential of a solution, its potential impact and measures of how we could accelerate the adoption in the market. We divided the market transformation curve into three areas: innovation, market uptake and the completion of the market transformation. Coming back to research challenges and opportunities, I strongly believe that the principle of market transformation must remain in the back of our heads when we identify research opportunities that are relevant to society.

Major developments affecting lighting

I would like to outline how the guiding principle can be applied to the field of lighting by focusing on three recent technological developments that have the potential to impact our society in a substantial way:

- the Digitization of Light,
- the Internet of Things, and
- Big Data.

In a keynote speech given at the outreach event of the Intelligent Lighting Institute last year, Mr. Kees van der Klauw spoke about the “Digitization of Light” [18]. LED technology has reached a level of maturity required to succeed in the lamp market. The market transformation towards LEDs has begun. In some North American jurisdictions the market transformation is being accelerated through incentive programs such as those offered by electric utilities.

The digitization also offers a different means of operating and utilizing equipment, and therefore also lighting equipment. The Internet of Things (IoT) has become a focal point. Devices with computational ability can connect to the internet and subsequently interconnect. Interconnecting existing and new lighting infrastructure can be used for lighting control based on more information than conventional solutions consisting of an occupant sensor alone.

Interconnected devices generate data that need to be analyzed. The more devices connected to the internet, the more data become available. Big data has become the synonym for the challenges and opportunities arising from the interconnection. The ability to process a huge amount of data in real time and to filter relevant from irrelevant information leads to many interesting questions in the field of smart lighting.

The three developments, the digitization of light, the Internet of Things and the concept of Big Data all enable and depend on each other in the field of Building Lighting. The number of possibilities in applications is huge. Our task must be to apply those that have a good potential and great benefits to society. I regard this as very exciting times in the field of lighting research.

Research Project

I would like to provide you with an overview of the research line “Creating Healthy Environments” in which the building lighting group is involved. The general idea is to obtain a good balance between the Health and Energy areas via optimized solutions for areas such as lighting, acoustics, air quality, thermal comfort and ICT. This research line is being applied on building types, the first two focal areas being hospitals and offices. The lighting-related activities are also part of the project portfolio within the Intelligent Lighting Institute (ILI) under the program line “Sound Lighting”.

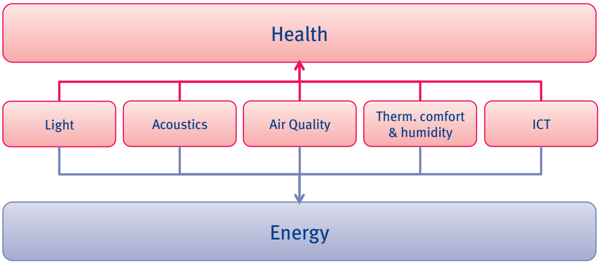

Figure 8

Structure of the research line “Creating Healthy Environments”

I would like to focus on the research related to offices. Recently, the new office building “The Edge” became operational in Amersterdam-Zuid. The building is utilizing a number of new technologies, some of which are related to building lighting. All of the more than 6,000 luminaires are equipped with LEDs, host 5 sensors each (occupancy, photo element, temperature, humidity and CO_2) and are connected to the Ethernet. They send and receive data over the Ethernet and are powered over the Ethernet [19].

The connection of the lighting system to the internet allows the interaction between lighting components and other connected devices. With the help of a smart phone, a building occupant is able to control the lighting in his proximity when the settings do not match his personal requirements. Such settings can be learned by the system and reproduced when this very user returns to this or goes to any other area. This allows the system to reproduce users’ preferences automatically. I want to outline some of the research questions that we plan to investigate over the coming period:

Occupancy Patterns in Office Environments

With many data collection points directly related to the lighting system and its behavior in accordance with the detected presence, a systematic collection of occupancy patterns can be obtained. This will further inform specific data used for the estimation of the energy use for the end use lighting in buildings; current methodologies in standards still rely on mainly expert opinion and only a few data sets. With better understanding of the occupancy patterns, control strategies for lighting, especially in open offices, can be advanced along with input for space planning in the field of flex offices. Occupants with similar presence patterns can be grouped together so that the energy use for lighting can be further reduced.

Health Impact of the Lighting and Climate Control System

Location and lighting preferences of individuals allow the estimation of the effective irradiances and exposures they receive for health-impacting effects throughout the day. Correlations with health-related complaints will indicate to what extent the lighting and overall indoor climate situation can enhance the comfort and well-being of building occupants. The benefit of this knowledge contributes to a reduction in days off sick, acceptable ranges for “colored” lighting and the attempt to avoid specific discomfort issues such as dry-eye symptoms.

Human Interaction with the Building Management System I:

Recording the interaction of building occupants with the control system informs about situations where the settings determined by the automated control systems do not match the expectation of the occupant that is related to general personal preferences as well as the current activity (very much influenced by the visual task). This “closed-loop” feedback gained through the user’s interaction allows the implementation of a “learning” algorithm. By carefully injecting deviations to the control system, the overall sensitivity of individuals can be tested and acceptable ranges for particular parameters can be derived.

Human Interaction with the Building Management System II:

The interaction of one individual with the building management system aims directly at optimizing the indoor environment for that very individual. But when a building occupant interacts with others, as in a meeting room, conflicting preferences need to be managed. This leads to two general paths for the optimized lighting situation:

- “Follow me” ensures that the individual preferences are applied in all areas where the building occupant goes and works.
- “Consider me” addresses the situation where conflicting preferences collide but are taken into account by the control algorithm within a particular building space.

This project example illustrates the application of the strategy for building lighting in various ways. It addresses the lighting-related aspects of energy, environment and health and therefore contributes to the three pillars Light & Energy, Light & Environment and Light & Health of the chairgroup. The research opportunities are also directly related to the major developments I had outlined before : Digitization of Light, Internet of Things and Big Data.

Summary

My vision for the Chair Building Lighting is aligned with the aforementioned focal points and strategies of TU/e. I believe that the exciting opportunities that building lighting has to help find solutions for societal challenges will provide a chance for innovative ideas:

- that will be initiated through research activities, in collaboration with industrial partners,
- that may open up entrepreneurial opportunities for individuals who see their potential, and
- that will help us to provide answers to the questions derived from societal challenges.

I am looking forward to taking on these challenges and to working together with partners on and off campus to develop answers and solutions for Building Lighting that focus on

- energy,
- environment, and
- health.

Lighting needs to consider and balance these three aspects in order to best serve its user: the individual human being. Lighting research will inform further what good lighting is. Some findings will lead to benefits in one pillar but may adversely influence another. I believe the solution lies within a well-balanced mix.

Acknowledgements

There are many individuals and organizations that have supported me. Without their help, I would not be standing in front of you. I would like to express my gratitude to all those who have believed in me and supported me along the way.

I wish to thank the Executive Board of the university and the department of the Built Environment represented by our dean Elphi Nelissen for putting their trust in me and appointing me chair Building Lighting.

I would like to thank the chairholders in the unit of Building Physics and Services, Jos Brouwers, Jan Hensen, Bert Blocken and Wim Zeiler as well as Helianthe Kort for helping me to get started, for offering their help and for answering all my questions in recent times.

In an equal manner, the TU/e Intelligent Lighting Institute has welcomed me and helped me to get started. It would take too much time to name everyone, so I will just mention our director prof.dr. Emile Aarts and the Program Manager for “Sound Lighting” prof.dr. Yvonne de Kort.

Thank you very much to the members of the Building Lighting group, prof.dr. Evert van Loenen, dr. Myriam Aries, Mariëlle Aarts, Jan Diepens and our PhD candidates for contributing to a positive work climate and helping with the implementation of our vision.

A very special person who has been supportive in numerous ways and over a long period of time, is my own doctoral supervisor Prof.Dr. Heinrich Kaase. Not only did I learn lighting from him but he has been a great supervisor and mentor during my PhD and habilitation. Everything that I have learned from him created the foundation upon which I have been able to base my academic career.

Many colleagues with whom I have worked together have also contributed a lot as we have all been able to learn from each other:

My colleagues from TU Berlin Dr. Sven-Holger Kloss, Dr. Sirri Aydinli, Dr. Thomas Müller, Dr. Mehmet Yeni and Dr. Felix Serick shared their views on lighting-related questions with me in many valuable discussions.

I also would like to thank Dr. Steve Selkowitz from Lawrence Berkeley National Laboratory and Prof. Lorne Whitehead from the University of British Columbia for my time at their institutes.

My time at the electric utility BC Hydro in Canada was positively impacted by superb colleagues like Roy Hughes, Toby Lau, Dr. Cristian Suvagau, Nikolay Smirnov, Dr. Constantin Pitis, Bojan Andjelkovic, Ken Tiedeman, Paulus Mau and many many more.

Mike Hopkins and all other project managers I worked with in standardization at CSA helped me gain a deeper understanding of the processes and taught me the ropes so I could participate efficiently in standardization committees as both a committee member and a committee chair.

Apart from my professional life, there is also my personal life and I would like to thank my family for their ongoing and never-ending support. My gratitude includes my parents who have been the best parents a child can wish for and who have stood by me all the time. Similarly, this also applies to my sister Susanne and her husband Thomas.

Last but not least, my sincere thanks go to my wife Gabi and my son André. Gabi you have been tremendous in your support and have mastered the challenges that came with the move from Vancouver to Eindhoven in an exemplary manner. André, your smiles and happiness provide me with so much energy and motivation. I am proud of my family!

Ik heb gezegd.

References

1. European Commission, Horizon 2020 - The Framework Programme for Research and Innovation, Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions, COM (2011) 0808 final
2. U.S. Patent 223,898, Electric-Lamp by Thomas A. Edison
3. Royal Swedish Academy of Sciences, Efficient Blue Light-Emitting Diodes Leading to Bright and Energy-Saving White Light Sources, Scientific Background on the Nobel Prize in Physics 2014, October 2014, available on http://www.kva.se/
4. Royal Swedish Academy of Sciences, Blå lysdioder – en uppfinning som sprider nytt ljus över världen, Populärvetenskaplig Information, 2014, available on http://www.kva.se/
5. IEA, Daylight in Buildings - a source book on daylighting systems and components, A report of the IEA SHC Task 21 / ECBCS Annex 29, International Energy Agency, 2000
6. Scartezzini, J.-L., Courret, G., Anidolic Daylighting Systems, Solar Energy Vol. 73, No. 2, pp. 123–135, 2002
7. Whitehead, L.A., Brown, D.N., Nodwell, R.A., A New Device For Distributing Concentrated Sunlight in Building Interiors, Energy and Buildings, 6 (1984) 119 - 125
8. National Research Council Canada, National Energy Code of Canada for Buildings, 2011
9. Ehling, K., Tageslichtsysteme: Lichttechnische Bewertung und Wirtschaftlichkeit, Dissertation TU Berlin, 2000
10. Knoop, T., Tageslichtabhängige Beleuchtungssysteme auf der Basis von Installationsbussen, Dissertation TU Berlin, 1998
11. Boyce, P.R., Human Factors in Lighting, Third Edition, CRC Press, Taylor & Francis Group, ISBN 13-978-1-4398-7488-2, 2014
12. Newsham, G., Brand, J., Donnelly, C., Veitch, J., Aries, M., Charles, K. (2009) Linking indoor environment conditions to job satisfaction: a field study, Building Research & Information, 37:2, 129-147

13. Mangkuto, R.A., Aries, M.B.C., van Loenen, E.J., Hensen, J.L.M., Analysis of Various Opening Configurations of a Second-Generation Virtual Natural Lighting Solution Prototype, LEUKOS, Journal of the Illuminating Engineering Society of North America, 10:223-236, 2014
14. Kaase, H., Serick, F., Licht und Gesundheit, Tagungsband Erstes Symposium Licht und Gesundheit, Berlin, Germany, 2000
15. Piazena, H., Kockott, D., Uebelhack, R., Individuelle Bewertung der circadianen Wirksamkeit solarer und künstlich erzeugter Strahlung, Proceedings of LuxEurope 2005, pp. 29-32, Berlin, 2005
16. Yeni, M., Optimierte Gerätetechniken für UV- und Lichttherapie, Dissertation TU Berlin, 2005
17. van Bommel, W.J.M., van den Beld, G.J., Lighting for work: a review of visual and biological effects, Lighting Res. Technol. 36,4 (2004) pp. 255–269
18. Van der Klauw, K., The Digitization of Light, invited keynote speech at ILIAD 2014 - The 2014 edition of the annual ILI public outreach event. Eindhoven, The Netherlands, 2014
19. Ubels, E., The Edge project realiseert innovatie in beheer van vastgoed, Building Holland Talks, May 2014

Curriculum Vitae

Prof.Dr.-Ing.habil. Alexander Rosemann was appointed full-time professor of Building Lighting in the Department of the Built Environment at Eindhoven University of Technology (TU/e) on April 1, 2014.

Alexander Rosemann (1972) graduated in electrical engineering (1997) at the Technical University of Berlin (TUB). He gained his doctoral degree 'Dr.-Ing.' (2001) at the TUB faculty of Electrical Engineering and Computer Science. He has been a visiting scientist at the Lawrence Berkeley National Laboratory (LBNL) and the University of British Columbia (UBC). Rosemann continued as a research scientist at TUB before joining the façade manufacturer schüco international KG in 2004. In the following year he became a postdoctoral fellow with UBC. In 2007 Rosemann received his habilitation at the TUB and joined the electric utility company BC Hydro in Vancouver where he was responsible for energy-efficient lighting projects and energy-efficient standardization, regulations and building codes. He has chaired several standardization committees and contributed to the National Energy Code of Canada for Buildings. In April 2014 Rosemann was appointed full-time professor of Building Lighting in Eindhoven. He has published over 70 publications and is a member of the NSVV (Nederlandse Stichting voor Verlichtingskunde), LiTG (Deutsche Lichttechnische Gesellschaft), IES (Illuminating Engineering Society) and CIE (International Commission on Illumination). Alexander Rosemann holds joint German and Canadian citizenship.

Colophon

Production
Communicatie Expertise
Centrum TU/e

Cover photography
Rob Stork, Eindhoven

Design
Grefo Prepress,
Sint-Oedenrode

Print
Drukkerij Snep, Eindhoven

ISBN 978-90-386-3806-5
NUR 955

Digital version:
www.tue.nl/bib/

Visiting address
Den Dolech 2
5612 AZ Eindhoven
The Netherlands

Postal address
P.O.Box 513
5600 MB Eindhoven
The Netherlands

Tel. +31 40 247 91 11
www.tue.nl/map

Technische Universiteit
Eindhoven
University of Technology