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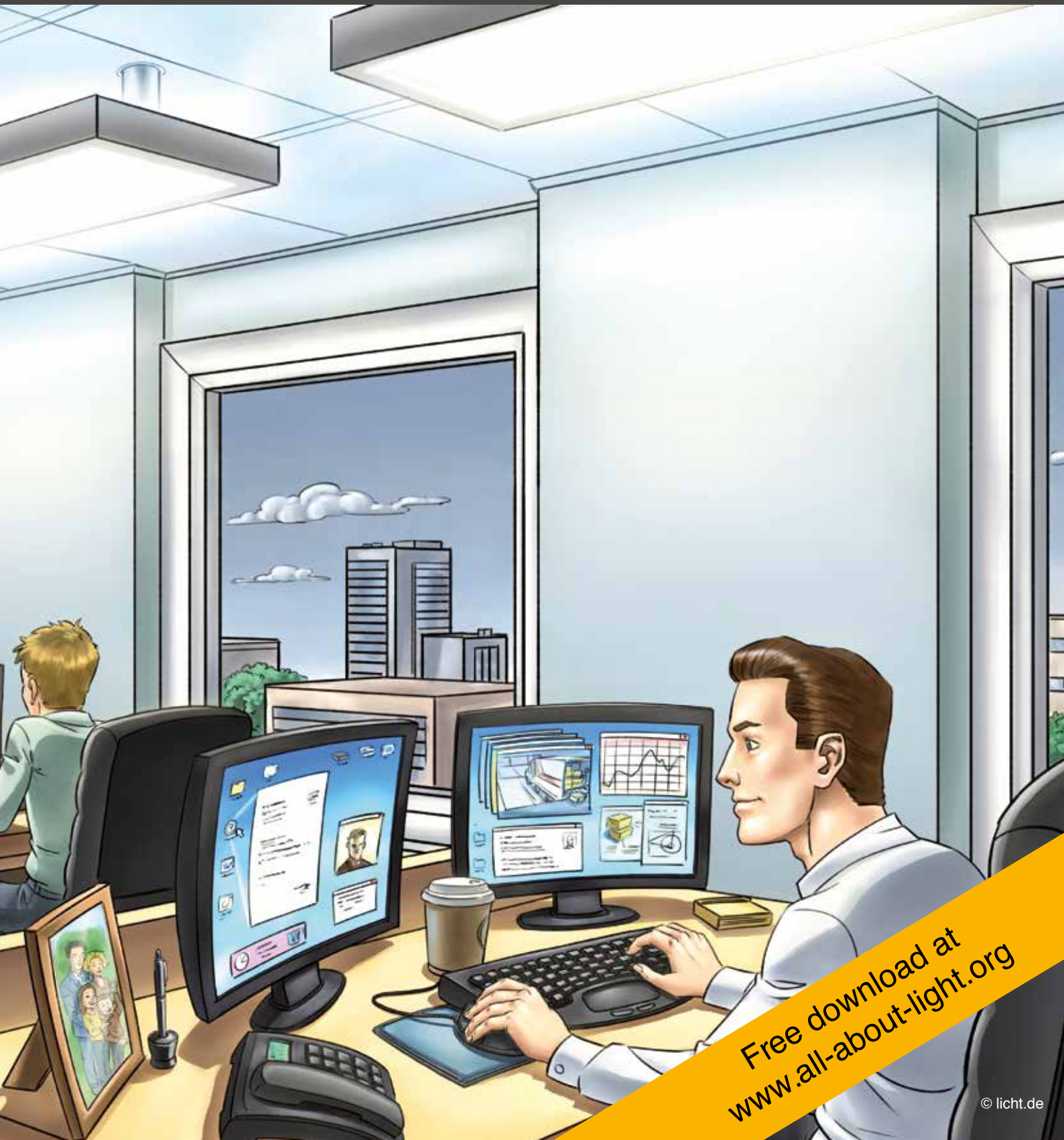
Guide to Human Centric Lighting (HCL)



Preface

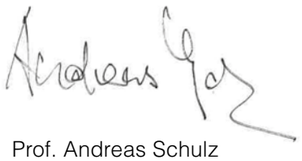
With the invention of electric light and the subsequent industrial revolution at the beginning of the 20th century, a society has developed which could not have emerged without this innovation.

The transition from “conventional” electric light to digital LED technology is a paradigm shift that is taking place at a rapid ppace. For engineers, this means adding new “quality features” apart from managing physical variables and known criteria such as contrast and glare. With the advent of **H**uman **C**entric **L**ighting (HCL), aspects such as the colour temperature and intensity of the light combined with illuminated material and human perception play a new role. In addition to the visual impact and power efficiency, it is now about optimizing the biological and emotional impact of light on human beings.

The focus is on the recipient and its specific requirements. This guide aims to provide guidance and instructions for architects and designers who are facing new challenges. It has been prepared to provide a tool for interested designers and architects to implement HCL. The guide illustrates what the term Human Centric Lighting covers. Practical examples show how users can develop HCL concepts for different room scenarios and uses such as industry, school, office and in private residences. The guide further covers the requirements of a modern society with flexible working days, shift work or early start of school days.

Light is more than a medium that enables us to see: Light determines our mood and sleep rhythm – it stimulates us and calms us down. It is essentially responsible for the acceptance of our spatial surroundings. More and more consumers and customers become aware of the importance of modern lighting. A market research conducted by the international consulting firm A.T. Kearney forecasts that Human Centric Lighting will gain a non-negligible influence on the lighting market in the medium term. The demand is steadily growing. Architects and engineers need to be prepared to meet the new demands of their customers. A modern light design means to have an HCL-compliant design process in place – systematic and with a long-term effect. Such a design and HCL-compliant operation can enhance the productivity and people’s well-being. The important aspect here is that one has to take a comprehensive view of all factors – from colour temperature to light direction – and align them with one another. In addition to the visual and biological impact, the emotional impact of light in a room must be given a strong emphasis. Engineers and architects need to be aware of these aspects and integrate them in their planning process from the beginning.

Best regards



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Editorial

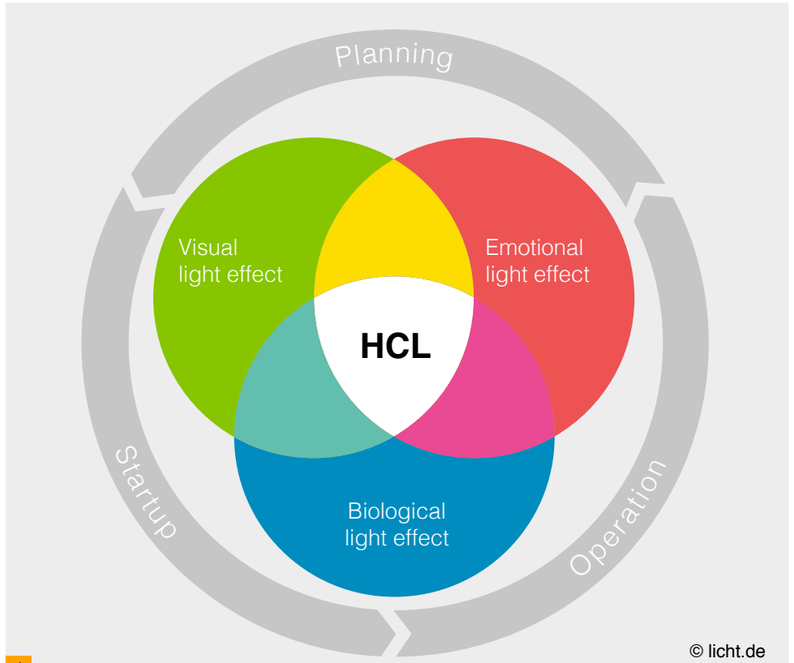
Being able to see is a miracle of evolution. Our sense of vision ensures spatial orientation, targeted movements, controlling our inner biological clock, experiencing emotions and communicating through gestures, signs and writing.

Our eyes are the mediator for vision, with the cones enabling us to see colours and the rods allowing night vision. The cones need light to a sufficient degree. In low light conditions, the rods allow perceptions also at low brightness levels, however without colour impression.

A third photoreceptor was not discovered until the turn of the millennium. It is directly related to the regulation of our inner clock (SCN). Those so-called ganglion cells respond to visible light in the short-wave “white-blue” spectral range. The protein melanopsin, which is contained in the cells, is stimulated through this light, causing the suprachiasmatic nucleus, the central control point in the brain, to receive stimulus. This stimulus is transmitted through the connection between the retina and hypothalamus, where the SCN is located. It is the central control point that precisely synchronises both our inner clock and our activities and productivity.

In the evening and at night, the pineal gland (epiphysis) secretes melatonin, which is among other things responsible for healthy sleep. In the morning and during the day, the level of melatonin in the blood then ebbs, while other messenger substances activate the body. This circadian rhythm is determind particularly by light (more information see licht.wissen no. 19). The third receptor provides stimuli for the sleep-wake rhythm. This rhythm is usually determined by natural daylight. For the physical and mental health of human beings it is hence advisable to let their life rhythm follow the natural progression of daylight and to use natural light wherever possible.

Our working environment, however, often requires us to deviate from the natural day/night rhythm. In northern latitudes, working time often stretches over the dark morning and afternoon hours. Artificial light sources generally extend the light periods of the day and allow activities round the clock. With artificial lighting available at all times, our working and living environment has changed, turning the night into day. Until recent times it was good to switch on the light for a better vision and to be able to perceive our environment. In addition, at night the motto is often: the more light, the more attention. Acknowledging the fact that light brings us not only a better vision and a more impressive environment, but that it can adversely affect natural fatigue in the evening and sleeping behaviour at night, the right lighting at the right times demands more care and attention.



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The main focus of lighting solutions should be on humans. Human centric lighting offers the chance to develop holistic lighting concepts, ensuring better harmony with our natural rhythm.

This guide examines in detail the multiple characteristics of light and their impact on human beings from a visual, emotional and biological point of view. Human centric lighting provides a basis to create the best possible interplay between artificial light and natural daylight. This requires careful planning. Installation and operation have to follow the planning guidelines. In a general context, this guide elaborates user and operating information, so as to systematically harness the advantages **H**uman **C**entric **L**ighting.

Definition

Light satisfies not only visual demands, it always has had an emotional and biological impact on humans as well. In drafting a lighting concept, humans are in the focus of attention – this is called **H**uman **C**entric **L**ighting, abbreviated: **HCL**.

Human **C**entric **L**ighting **(HCL)** stands for a lighting concept providing the intended light that is appropriate to the user’s individual living and working conditions at any time. To put it briefly, HCL concepts enable the right light for each time of the day and year. HCL is defined as follows:

> Light has various effects and it always works – visually, emotionally and biologically. Human Centric Lighting (HCL) has a specific long-term effect on our health, well-being and on the productivity of any human being through holistic planning and implementation of the visual, emotional and particularly biological impacts of light.

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HCL concepts need to be established in the project at an early stage, and they provide the basis for a holistic, interdisciplinary planning. Natural daylight is utilised where feasible from a design perspective. The lighting system is installed and operated in accordance with the lighting plan. The user receives relevant information to understand the benefits and to be able to operate the light.

Light has a different effect during the day than at night. The lighting concept should take this into consideration and therefore offer options to customize the lighting. Options for customization are a prerequisite for good illumination, so that the demands for good visual quality are met. Moreover, lighting designs spaces. If no daylight is available, an artificial light situation arises with its own identity. This artificial light situation is not intended to distort the existing perception of space. Finally, light has a biological impact. During the days, a more activating effect is expected, whereas in the evening, they should rather be avoided to stabilise the circadian rhythm. Therefore, the lighting should allow a dynamic transition between various lighting scenarios – from morning, throughout the day, to evening and night. A particular case is shift work at night (more information about shift work on page 22).

In many cases, the approach of bright lighting similar to daylight during the day and warm-white lighting, with reduced brightness levels in the evening is adopted.

When we take a closer look, the HCL concept is considerably more demanding and goes clearly beyond merely adaptating illuminance and colour temperature, as the impact of lighting is considered from an integral point of view. Apart from visual tasks and the biological impacts, it also considers the context in which the lighting is used. Is it a focused, performance-oriented environment or should the lighting have a more relaxing effect? Do the requirements change throughout the day? Are there different spatial areas for different tasks? Other aspects (e.g. light to support creativity or for calming down) may present further demands on the lighting concept.

The targeted and professional use of light for therapeutic purposes goes beyond regular HCL and is not covered by this guide.

The ultimate aim of light according to the HCL concept is to serve the user, be operated by them and to meet their expectations in the long run.

[1] The image shows the three effects that are crucial for HCL concepts. HCL concepts need to be considered as early as in the planning and startup phase and during operation.

[2] Definition of Human Centric Lighting provided by ZVEI. See position paper of ZVEI as of September 2016 at: www.zvei.org/presse-medien/publikationen

Detailed view of HCL approach

For a lighting design to be implemented in an energy-efficient manner and to ensure long-term effect on humans, health, well-being and productivity it should provide an integrative, holistic lighting and space planning as well as appropriate installation and implementation. The application and effect of light must be included in the planning process from the outset. It is important to closely coordinate all trades, products and materials. Only a long-term lighting system, operated and functioning in accordance with the planning guidelines, meets the needs of the people.

HCL serves to implement a holistic and targeted approach, with the planning and operation of lighting systems focusing on humans. In principle, light always has an impact on humans – whether consciously or unconsciously. The effect can be planned or unplanned. It is therefore necessary that the planning is made on the basis of needs-oriented criteria.

According to the HCL concept, the following terms set standards: visual, emotional, biological as well as targeted and long-term. In detail this means the following:

Visual
Good receptibility makes working easier. To achieve this, normative and statutory frameworks contain minimum criteria, aiming at performing visual tasks in various activities and workspaces. Standards such as DIN EN 12464-1 “Indoor workplace lighting” contain minimum values engineers need to apply when designing lighting systems. The operator ensures observance of the lighting criteria based on the Workplace Ordinance ASR A 3.4. The DGUV ordinance contain a useful guide to the operation of lighting.

The aim of the design process and operation should always be to provide optimal visual conditions. Individual particularities such as a greater need for light for elderly people are to be individually planned and customized.

Emotional
To support the well-being of humans within their social environment, one needs to take into account criteria based on architectural, formally aesthetic and perception psychology aspects and on the user’s expectations. These criteria follow rules and interdisciplinary guidelines arising from good practice. They are hard to grasp in numbers and cannot be found in relevant standards and regulations. If one takes into account an appealing design for the room with light and all its formal elements that fulfils the expectations of the users, one can assume more acceptance, satisfaction and well-being.

Biological
Biological impacts must be considered and planned very carefully. They have an effect on the circadian rhythm and can support the need for more productivity during the day on the one hand and for a better sleep at night on the other. For a short period of time, they are able to encourage attentiveness and alertness.

DIN SPEC 5031-100, DIN SPEC 67600 and the new DGUV Informative Document on non-visual impacts of light in the context of industrial safety contain notes and recommendations on the planning of biological or melantopic impacts.

A well thought-out HCL concept can avoid adverse biological effects caused by improper lighting at the desired time.

Targeted
Targeted means that the aim of HCL concepts is to achieve positive effects on humans, that are geared towards their expectations and they can understand and utilise. The concepts take fully into account the effects of light.

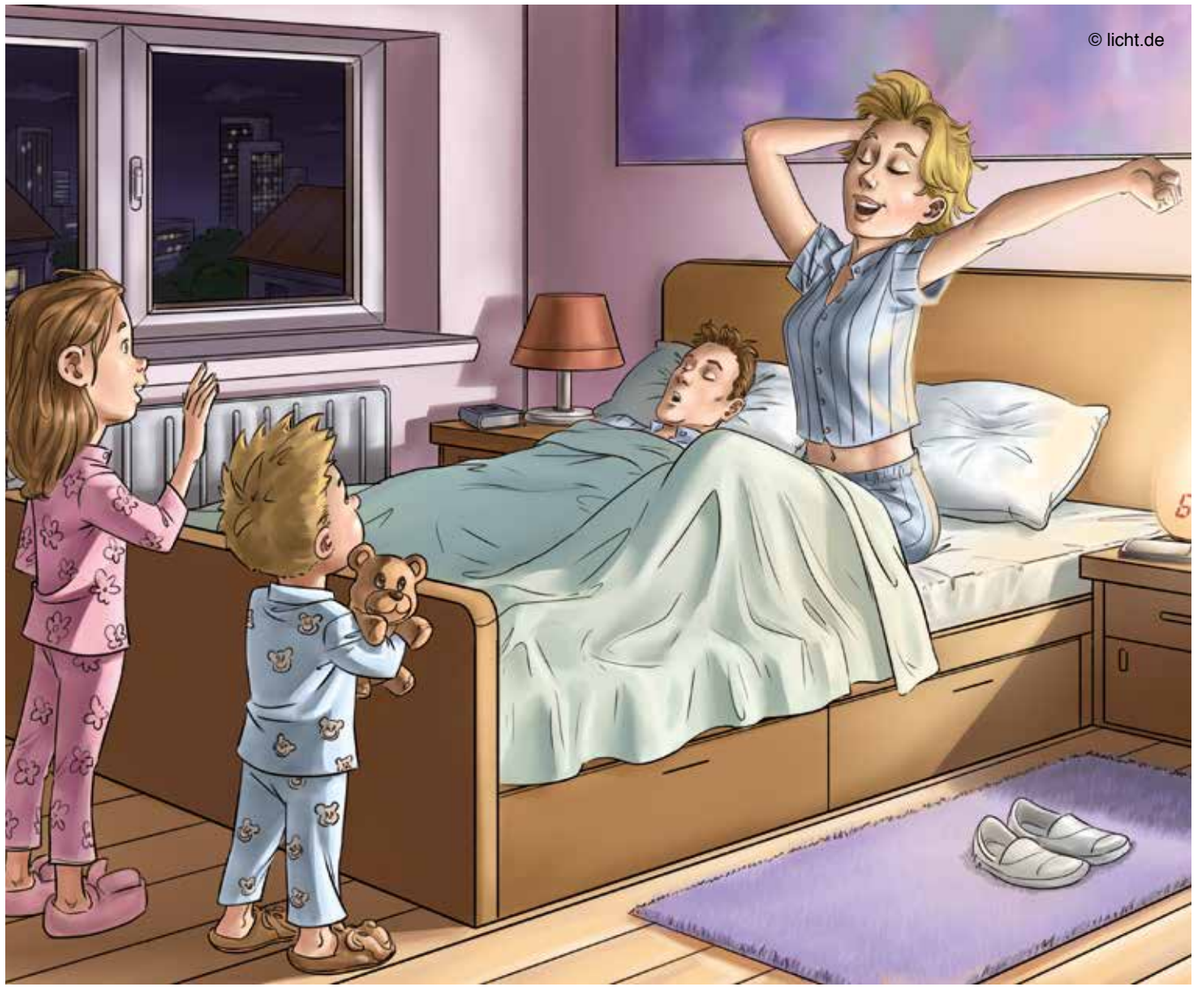
Long-term
Long-term means that the visual, emotional and biological effects are lasting and positive. They include also short-term effects, for example to encourage alertness, provided that they have no long-term negative effect such as on sleeping behaviour. Furthermore, “long-term” refers to the aim of ensuring or improving long-term operation of the lighting system in accordance with the instructions of the designer.

The user needs to be informed about the operation and effect of the HCL concept.

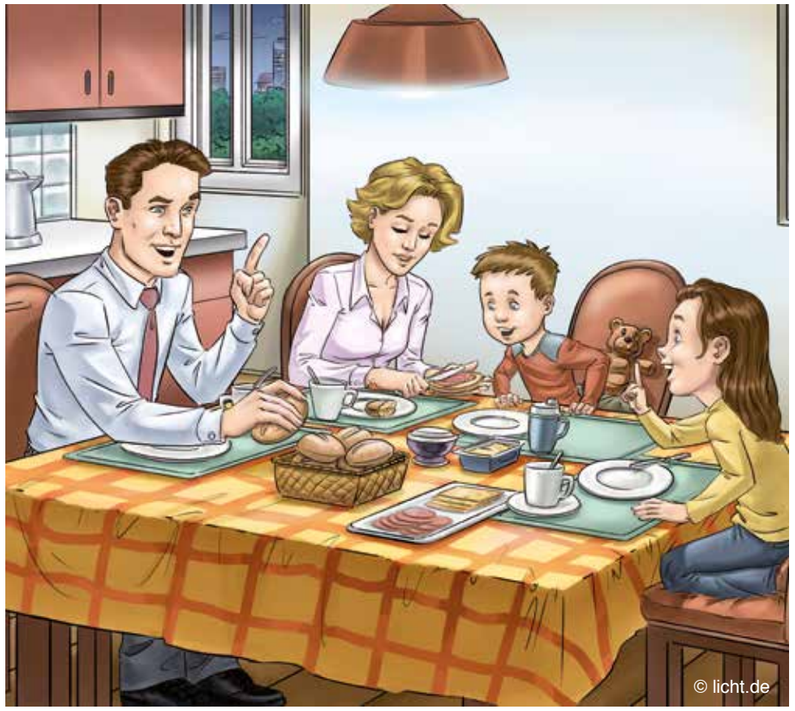
With HCL throughout the day

An exemplary daily routine
Light has various effects and it always works – visually, emotionally and biologically. With Human Centric Lighting, the user experiences the right light at the right time. Humans notice the effect either subconsciously or experience it consciously. A typical feature of HCL lighting concept is the dynamic lighting that simulates the natural course of daylight switching between various lighting scenarios. People’s daily routine is originally influenced by the daylight brightness curve. Nowadays at work, however, we can experience this rhythm in a natural manner only very rarely. People today usually spend their days in indoor spaces under the dictate of time, which are not geared to daylight.

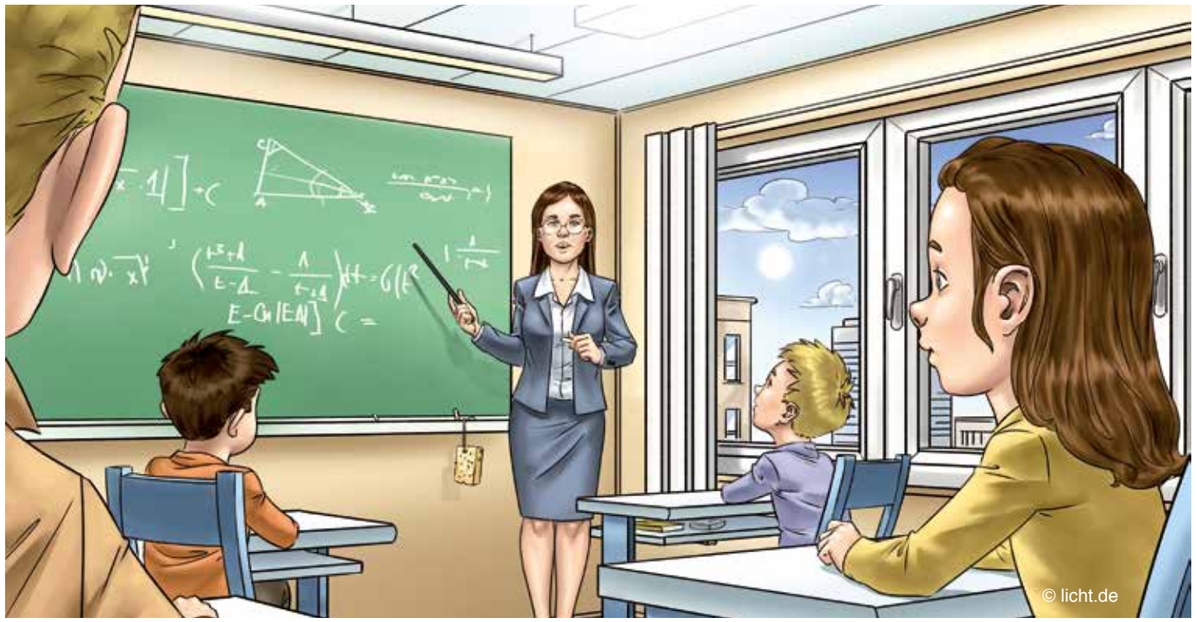
How does a human experience a day when he or she is supported by artificial light in the best possible way?



6 a.m.: For most people, the procedure of getting up repeats itself in the morning at approximately the same time during the week. For some, as early as 5 o’clock, while for others as late as 8 o’clock. In many cases, we wake up to an alarm clock, often at a time that does not correspond to our own natural rhythm when we, depending on our chronotype, have not had enough sleep yet. By gently rising brightness, artificial light can facilitate waking up and help start the day. Artificial light can further help to bring our individual sleep rhythm closer to the desired wake-up time (light alarm clock).



7 a.m.: At breakfast, a brighter and activating light in daylight quality (with a higher blue content) can support a quicker start into the new day. Light sources such as panel lighting on the walls (wallwasher) distribute the artificial light evenly and thus create a pleasant atmosphere where one can wake up with coffee and warm rolls.



8 a.m.: The start of work or classes – both in the summer and in winter – can be supported by bright planar light. Visually with the illuminance normatively required for the visual task; biologically with a light colour geared to daylight and corresponding vertical brightness on the eye, preferably planar light shining from the ceiling or wall. The right light helps students with their studies. Concentration increases, joint learning becomes easier and is more fun.

9 a.m.: During the working day, light supports people in their work. In a modern working environment, both the visual and the emotional effects of light are taken into account. Modern lighting concepts, tailored to the environment, facilitate work, increase concentration and are perfectly geared to the visual tasks of the staff. Care should be taken to observe the minimum values for the eyes by means of a sufficient, vertical illuminance level. Higher illuminance levels and light colours above 5,500 Kelvin help maintain performance and concentration for a longer time.

10 a.m.: Optimal production results largely depend on the employees' willingness to perform. Proper lighting helps boost motivation, prevents fatigue, maintains health and guards against accidents at work. Further, with regard to hall lighting it is essential to assign the lighting to the relevant application areas. In addition, the industry needs to take into account various working models (morning, evening, night shift) in planning and implementing lighting concepts.

12:30 p.m.: Break rooms, for example at school, nursery school or in a factory, should be designed in such a way they they appeal to the users and provide them a pleasant and motivating or relaxing light. It is generally recommended to spend breaks outdoors. Should this not be possible, it can be almost as pleasant indoors as outdoors. The prerequisite is that the indoor spaces offer a daylight-similar atmosphere. For this purpose, high colour temperatures should be use, as they ensure that reading and playing are almost as much fun as outdoors.

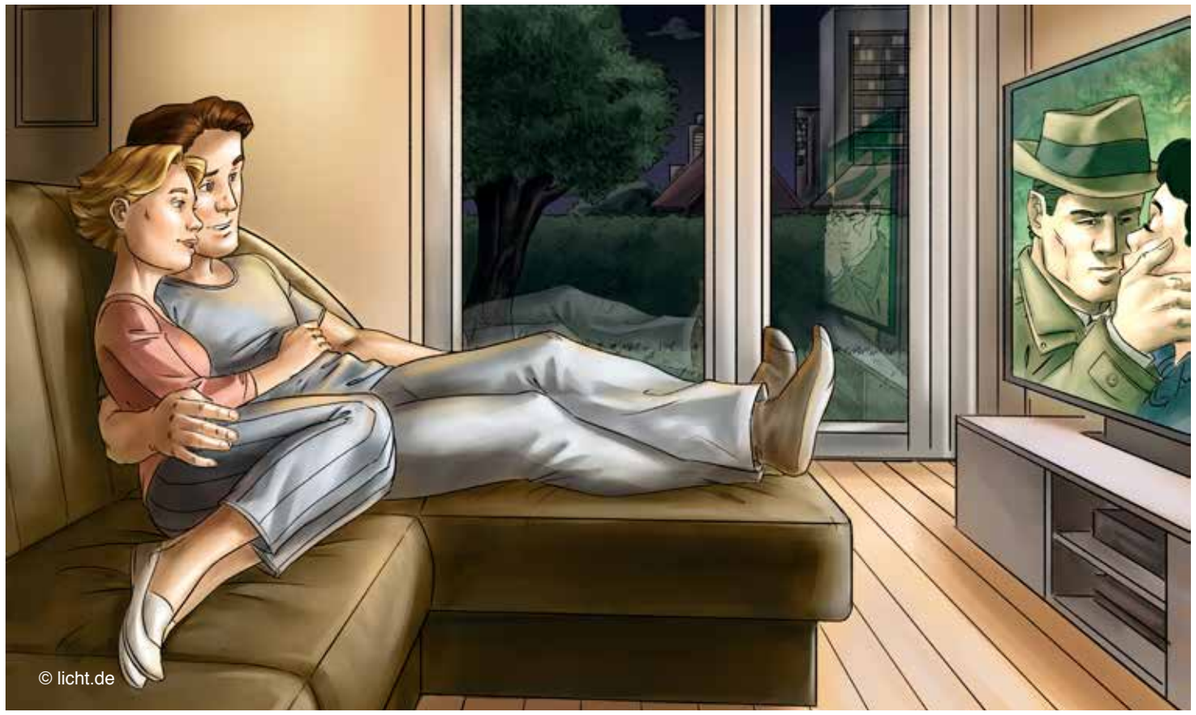
2 p.m.: For meetings and presentations the following applies: pleasantly designed spaces, motivating light mood for discussions and focussed light for presentations. Brightly illuminated surfaces and sufficient vertical illuminance levels prevent natural fatigue resulting from dimmed light. Various lighting atmospheres can be created on demand through artificial light emanating from luminous surfaces, brightly illuminated wall surfaces or large-surface ceiling luminaires.

5 p.m.: The end of the workday is also accompanied by specific lighting. After a hard day of work, switching to warm light colours is a sign of the approaching evening. On short days in winter, late risers, who start later in the morning and stay active for longer in the evening, can extend the natural daylight brightness even beyond sunset by means of artificial light. The light phases should take place with a certain degree of regularity. For the circadian system of an owl, it is “unnatural” to start work early in the morning, whereas it is unnatural for larks to be able to work in the late evening through artificial light. A few exceptions in individual cases are unproblematic. Having to constantly change between these two rhythms should be avoided.

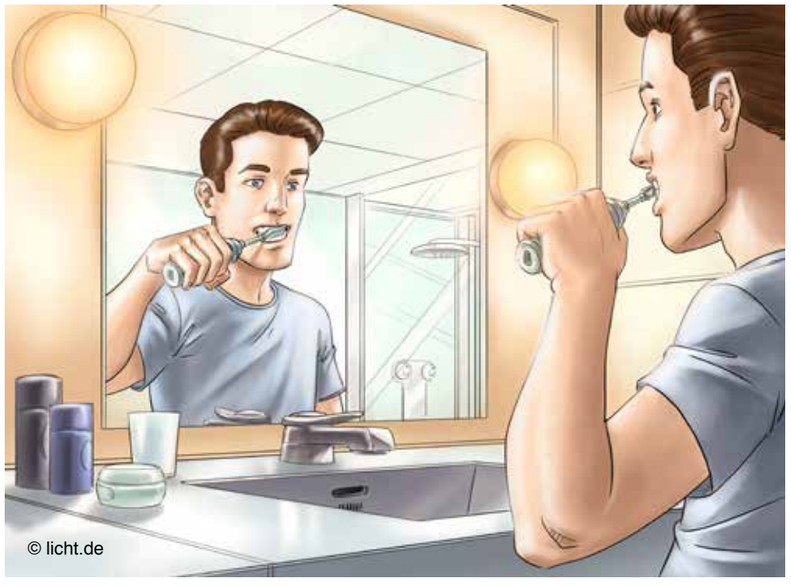
6 p.m.: Evening activities – be they shopping, eating out or other activities – these should be supported through suitable lighting. Supermarkets and shopping centres should use warm light colours in the late evening, while providing sufficient illuminance in order to perform the intended visual tasks. Dimmed lighting in warm colours is used in restaurants to create a pleasant and comfortable atmosphere. A welcoming atmosphere is also recommended for shops, as it supports not only the shopping experience after the daily stress, but also the anticipation of a dinner with the family.

7 p.m.: The day ends at home with warm light colours. Light should be bright enough that we feel comfortable and find our way around. Relaxation is now generally a priority!

8 p.m.: Some years ago, softwares were developed that can be installed on computers and used to adjust the background colour of the screen to suit daylight conditions. For iOS and Android there are now apps like “Nightshift” or “Night Mode” available to switch the background of the screen to warmer colours at sunset. This reduces the lighting effect on the biological system by 60 to 70 percent and helps reduce the light’s negative effects on sleep and regeneration.



9 p.m.: The light of a TV set influences melatonin secretion significantly less than looking at desktop screens or tablets. This is because, through greater distance and lesser bright components on the screen, lower illuminance on the eye is obtained.



11 p.m.: In the evening, while cleaning our teeth, warm white light, not too bright, (colour temperature between 2,700 and 3,000 K) is recommended in the bathroom. It is to be noted here as well that too many blue components have an activating effect and can make falling asleep more difficult.

HCL – Planning and operation

A careful and responsible planning for an HCL concept considers any possible effects of light, particularly as these effects interfere with each other. For example, a lighting that is to fulfil a certain visual task always has a biological and emotional effect as well. Conversely, a design should not consider only emotional or biological criteria, as it mostly needs to ensure compliance with visual requirements. It therefore requires normative and statutory requirements to be fulfilled. Compared to the usual designs of static lighting of the past, HCL concepts are characterized by their dynamic design as well as their targeted and long-term perspective.

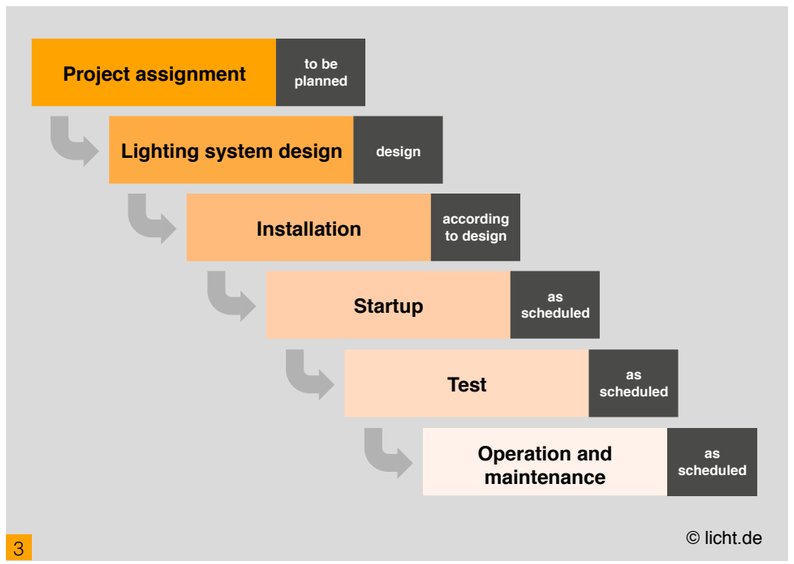
Planning process
The connection between the three effects of light is established through a targeted expert planning for long-term operation. Light has different effects at different times. Light close to natural daylight in the evening and at night, has a different effect on humans than during the day. Lighting designs incorporate this time-dependent effect of light into their concept. They use in nearly all cases so-called light management systems (LMS). The process describing the LMS design is documented in the new technical specification prEN/TS 17165 (scheduled release in autumn 2018). The process provides a sound foundation for a targeted planning in accordance with the HCL concept.

Thus, the lighting concept needs to consider the building's entire life span. Furthermore, the times and areas that are not the main focus, have to be accounted for and included in the planning. They have to be included into the user instructions (see fact sheet on page 18), as light always exerts an effect, anywhere and at any time. For this reason, lighting designs need to coordinate closely all relevant trades, involved technical planners and of course the users in a holistic and interdisciplinary manner.

The paper "Light quality – a process instead of a key figure" published by LiTG (www.litg.de) provides useful guidance on determining the requirements. Only when the lighting fulfils the criteria of the requirements, putting users at the centre, can the quality of the lighting solution be assessed.

Documenting the design
An efficient design contains detailed documentation, making it comprehensible and useful. In this aspect too, the lighting system design process provides structural guidance, so that the conceptual foundations of
- visual
- emotionalen and
- biological aspects

up to start-up can be tracked consistently, while also ensuring energy efficiency. This applies equally to the service sector and to industry, schools, healthcare, offices, and even in our own homes.



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[3] Sequence of lighting system design process: Project assignment – Planning – Construction – Operation.

[4] Project planning and documentation.

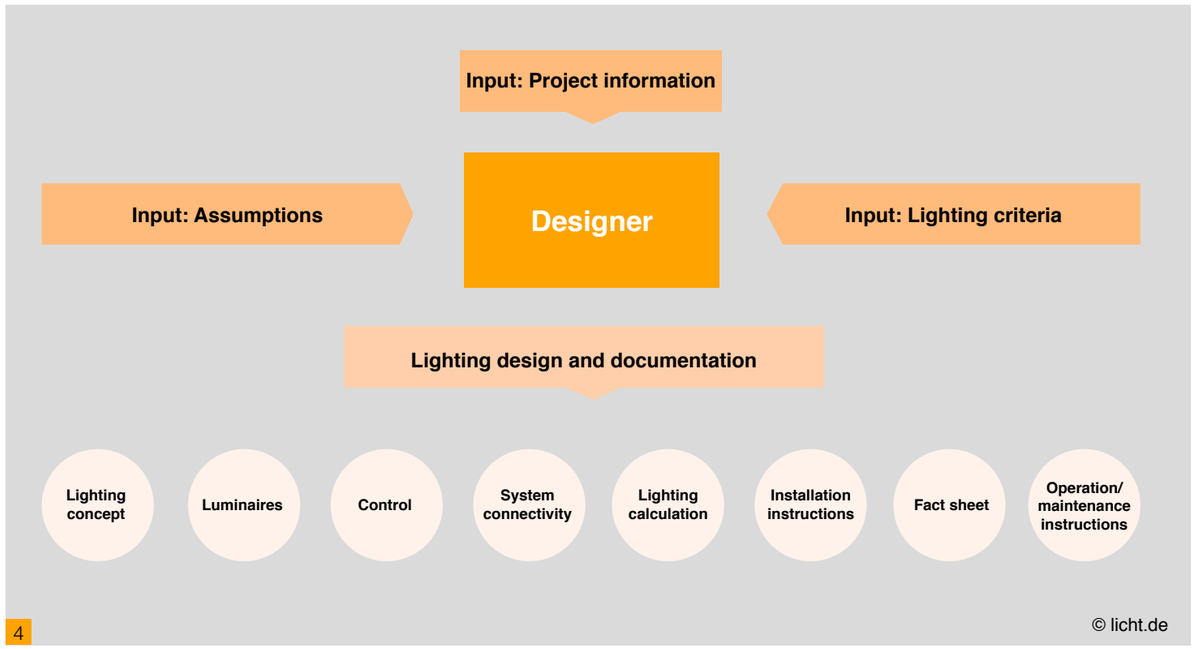
The construction design for the lighting system considers the normative and statutory provisions as well as the inspection requirements. This ensures that, for example, the expected energy consumption is met, without compromising the necessary lighting conditions. This document does not cover operating standards defined for the lighting.

Responsibilities of the designer
When a designer includes an HCL lighting concept into his design, he takes on a particular challenge with regard to his customer. The entrepreneur is responsible for his employees. Finally, a lighting concept supporting the people must be in the entrepreneur's interest. Parameters such as application usage, building, daylight situation, control and light technology are to be determined according to the needs of the user, whereas the user-specific requirements for the HCL solution are to be assessed from an ergonomic, psychological and biological point of view.

Based on this knowledge, the light designer develops the holistic conceept. After completion of the design phase, the designer creates a documentation containing the main documents (lighting calculations, visualisation, data sheets, light scenarios etc.) for implementing the concept. A documentation could include the following items:

Object analysis (and needs analysis)
- requirements determined through the work tasks
- requirements of project areas • needs and requirements of the people (users)
- requirements determined by the architecture
- Analysis of physiological and psychological requirements

Preparing a lighting concept
- Coordinating lighting moods and lighting strategy (distribution and direction of light in the room)
- Material-specific lighting
- Implementing the object analysis
- Specifying lighting requirements to the luminaires
- Determining luminaire arrangements
- Specifying light scenarios and lighting control
- Developing plans and documentation



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Planning parameters
The requirements of the user need to be determined in order to start planning. The human being is the focus of considerations, with the requirements of the user and their priority for their application being an essential prerequisite for the planning stage.
Certain aspects that should be considered as planning parameters are described below and by no means exhaustive. They can be divided into four groups:

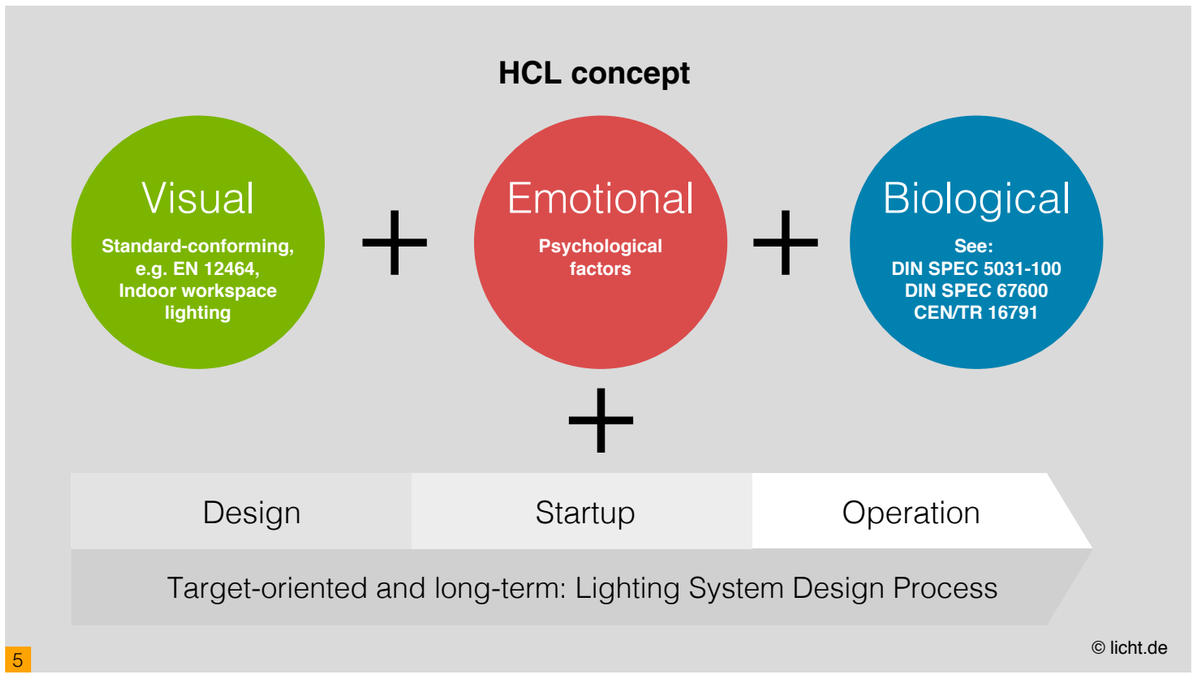
User
- Visual and work tasks
- Requirements of the user
- Usage time and duration
- Demographic facts

Buildings/rooms
- Usage requirements (including special characteristics)
- Surfaces and their characteristics (reflec tance values)
- Objects (cabinets/desks/machines) in the room
- Size and orientation of windows or day light openings, including light protection installtions
- Areas with particular visual tasks or requirements (e.g. colour rendering, light direction)
- Paths and spatial procedures (orientation and guidance through light)

Light technology and correlations
- Illuminance for visual tasks (e.g. DIN EN 12464-1)
- Melantopic daylight-equivalent illuminances at the eye (e.g. DIN SPEC 67600)
- Dynamics of illuminance and/or colour temperature
- Positioning of luminaires
- Interplay of luminaires (light moods)
- Light distribution (and change) in the room
- Luminances (large-surface luminaires)
- Luminances of light sources
- Accent lighting (focussing light)
- Direction of light focussed on visual tasks/surfaces in the room
- Duration and chronological sequence
- Materials and their impact in the light (reflection/transmission)
- Taking daylight into account
- Effect of glare/sun protection

Organisation/Control
- Use of rooms
- Working hours
- Position of control units
- Scenarios depending on day, week, month, year
- Motion-dependent control
- Scenarios/sequences to be selected and triggered by the user – centrally or locally
- Authority to enter/change scenarios
- Displaying the effect/implementation of scenarios (also remote display)
- Informing the user

Operating the lighting installation
During the design phase, the visual, emotional and biological effects of light are considered and applied during installation and operation. The needs of the users are to be considered in the planning stage and fulfilled during operation. It is particularly important to carry out checks of the lighting system for proper functioning at regular intervals. In certain circumstances, the user might not be able to detect errors directly in the functions. It is therefore necessary to maintain the lighting and in particular the lighting management on a regular basis.
Light scenarios changing over time or depending on certain usage, such as during different working hours or in meeting rooms, should be tested for proper functioning at regular intervals.



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Recommendations for users and effects
The user must be informed about how the lighting system works and how to operate it. A fact sheet (example illustration 6 on the fact sheet) provides answers and should include the following aspects:
- Notes on operating the lighting
- The benefit of daylight and electrical lighting

It should also include guidance on how to operate blinds or shutters and light protection devices.

Behind every professionally planned HCL solution, there is a lighting strategy with application scenarios. This strategy takes into account the specifications gained from the usage analysis. The designer needs to inform the user about reciprocal effects and impacts in order to prevent adverse light effects. Daylight white illumination at home in the evening just before going to bed can for example reverse the positive effect of warm white light at the workplace preparing the user for sleep.

Using HCL solutions properly can have positive effects within a very short time. To support concentration at the workplace or in schoolchildren, the use of white light during the day can have an activating effect, also for a short time. When students get restless in the classroom, use of warm white light can have a soothing and relaxing effect quickly. It is therefore essential to make information and operating instructions on proper use available for the user, so that he/she can fully utilise the lighting system. The HCL concept designer should prepare a fact sheet for the users of the lighting system, informing them about the purpose and effects of the lighting.

Fact sheet content

1) Operating the lighting
- Where are the control units?
- What control options exist?
- Where there is no control option: what does the automatic mechanism do?
  - a: The designer generates an automatic sequence (e.g. according to a pattern).
  - b: The lighting runs according to a specified sequence (curve); the user, however, can override the settings manually to meet individual needs (extend, relax, focus, pause etc.).

2) Use of lighting
- Lighting compliant with standards ensures performance of visual tasks.
- Lighting supports the well-being by changing brightness and light colour depending on the time of day.
- The lighting exerts a positive effect and supports the daily routine of the user.
- Potential risks are to be mentioned adequately.

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[5] HCL is a targeted planning process with a long-term effect, taking into account both the visual, biological and emotional effects of room light.

[6] To keep the user fully informed about HCL lighting, there needs to be a template on content that a fact sheet should include

For designers: template fact sheet

Below you will find a template on how a fact sheet can be structured and which facts it could include, thus explaining to the user the benefits and effects of HCL lighting:

Fact sheet on your HCL lighting

The aim of this fact sheet is to give you an understanding of the impact and operation of lighting installations.

Light has various effects and it always works – visually, emotionally and biologically.
Human Centric Lighting (HCL) has a specific long-term effect on our health, well-being and on the productivity of any human being through holistic planning and implementation of the visual, emotional and particularly biological impacts of light. By modifying the light colour and illumination level, the HCL light solution guides you throughout your day, helps you to do your work more easily or relax when necessary, all by allowing you to choose "your light".

But don't forget: Try to spend at least 30 minutes in natural daylight!

1) Operating the lighting
Here you can provide details on where the control units are located, which light scenarios were defined and what their effect is. The individual buttons should be clearly labelled (e.g. day light automation, concentration, relaxation etc.). The following examples can be used:

a) Example office: At the entrance door is a switch you can use to select three light scenarios:
- **(1) Scenario 1** (e.g. daylight automation: smooth change of light mood throughout the day and year according to incoming daylight)
- **(2) Scenario 2** (e.g. concentration: only for short periods, not after 10 PM)
- **(3) Scenario 3** (e.g. light during the break for relaxation)
- **(4)** On/Off

b) Example industrial workplace: At the workplace is a control unit you can use to select "your light" as needed.
- **(1) Task 1** (e.g. assembling)
- **(2) Task 2** (e.g. examining)
- **(3) On/Off**

Further notes:
Here you can describe further details depending on the HCL solution and the area of application. The following examples show possible options.

- The room is fitted with direct and indirect luminaires, with the indirect luminaires determining an automatic daily routine and the direct luminaires providing standard-conforming work light. This light is dimmable.
- You can also control the light at your workplace using your smartphone (add here information on download address: http:// ...). This way you can define additional light scenarios.
- You can operate the blinds manually at any time. When exposed to sunlight, the blind is closed to prevent glare and overheating.

2) Use of lighting
The aim is to make clear what benefits the lighting has to offer for the user. The wording should be adapted to the individual environment where an HCL solution is implemented. The example below shows a general wording:

The lighting supports the user's daily structure and well-being by gently adapting it to the current time of day and season. Working becomes easier, while proper lighting supports concentration and relaxation phases. The lighting is tailored to precisely meet the respective needs. In addition, you can decide to define "Your light".

3) Contact for questions
If the user has any questions concerning his HCL solution, a point of contact should be provided.

For further questions, please contact us by phone at (0123) XXXXXX.

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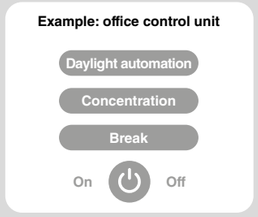

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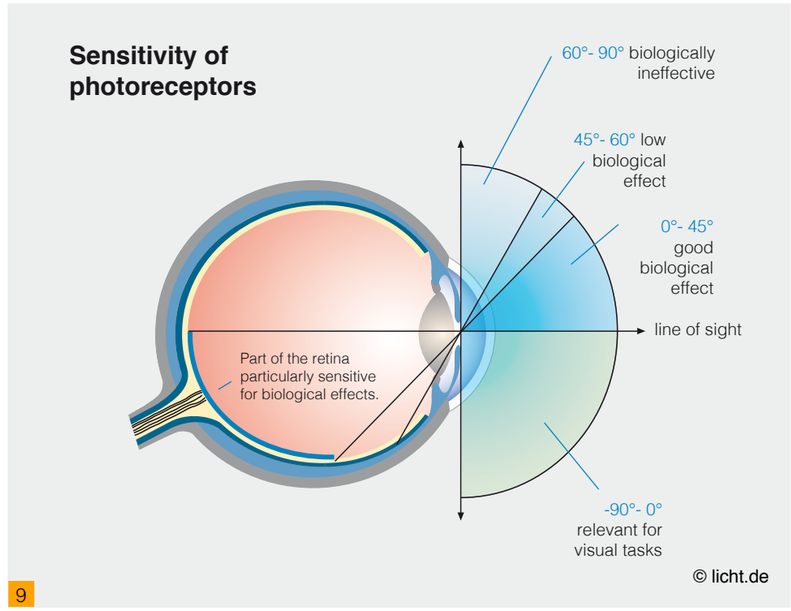
[7] Template of a fact sheet for designers.

[8] Examples for control units, allowing the user to set various lighting scenarios.

Values for the effects of light according to the HCL concept

For a lighting solution to be effective in accordance with the HCL concept, light colours and brightness track the natural course of daylight. The blue sky is nature's equivalent to achieve a stimulating effect. Consequently, large luminious surfaces illuminated with cold light have an energizing effect, while warm white colours help the user unwind. Apart from the biological effect, the visual and emotional effect of light is described as well.



9

[9] Depiction of ideal incidence of light of biologically effective light.

Visual impacts
The visual effects of light ensure the performance of visual tasks. For a visual task to be fulfilled properly, one has to consider illuminance, light colour, colour rendering, the cylindrical illuminance levels in the room, direction of light as well as reflection of rough surfaces. Established criteria are available to the light designers.

The lighting requirements for workplaces are laid down in the Workplace Ordinance (ArbStättV) and clearly defined by the Technical Workplace Regulation on lighting (ASR A3.4). For the design and implementation of lighting systems, relevant standards such as the DIN EN 12464 series of standards provide a meaningful supplement to these regulations.

The standard on lighting of workplaces states: "This European Standard specifies requirements for lighting solutions for most indoor workplaces that meet the needs of visual comfort and visual performance of people with normal visual ability. All usual visual tasks, including working at computer screens, are considered."(DIN EN 12464-1)

The following aspects of lighting are the prerequisite for a good lighting quality:
- Lighting environment
- Luminance distribution
- Degree of surface reflections
- Illuminance scale
- Visual task area
- Direct environment
- Background area
- Uniformity of illuminance
- Illuminance level measurement grid
- Physiological glare (shielding)
- Psychological glare
- Reflected glare
- Cylindrical illuminance

- Modelling
- Directional lighting
- Light colour
- Colour rendering
- Flickering and stroboscopic effects
- Illumination of computer workstations
- Maintenance factor
- Energy efficiency requirements
- Daylight
- Variability of light

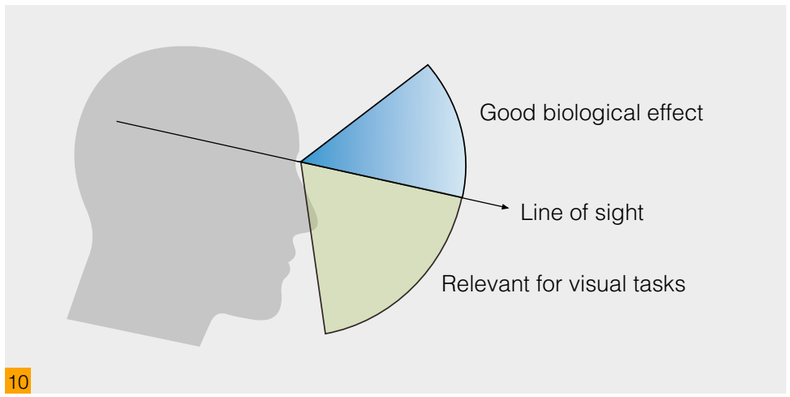
Emotional effects
The positive perception of a well-designed lighting system has been known for a long time. This involves not only the pleasant look and feel of luminaires, it is more a matter of the illuminated space and the light on surfaces and objects.

Proper light brings out the full and intended potential of the materiality of the space. Apart from the colour of light (warm light, cold light, RGB colour moods), the direction of light (wallwashers/illumination of walls, spots/highlights) have a particularly impressive effect. In outdoor areas, we see numerous “illuminations”, offering attractive views (facades, parks, public spaces). In indoor areas, the architecture of a space provides creative freedom, ranging from a “functional lighting” (satisfying standards) to a “stylish, playful or artistic lighting” (creative spaces, wellness lighting, shops, interactive areas in museums etc.).

Biological impact
Today, much is known about the biological effect of light (see licht. wissen no. 19). All this information enables us to considerably improve the quality of light in indoor spaces.
Apart from the visual effects, illuminance levels and light colours also exert a melanopic effect (further details on page 37 – melanopsia, melantopic effect).

Illumination
Appropriate illuminance levels allow the performance of visual tasks. Tailor-made lighting solutions can be developed to meet individual needs. A known fact is that elderly people need more light than younger for better vision, recognition and orientation. Although the world of lighting professionals has agreed on certain standards, particular cases or certain groups of users require tailor-made solutions. This also applies to the biological effect of light. A 60-year old person requires on average 30 to 50% higher lighting levels than a 30-year old person. In addition, changes in vision frequently coming with age such as cataracts must be further considered in the planning process. (DIN SPEC 5031-100).

Light direction
For the biological impact, the vertical illuminance on the eye should primarily be rated. Therefore, the direction from which the light hits the eyes is particularly important. The human field of vision in indoor spaces extends on an angular range of about 70° below and up to 55° above the line of sight (Sliney and Wolbarsht, 1980, see illustration 10). The sight is not static, but on average the eye is slightly looking downwards, as the visual task generally takes place in the lower part of the field of vision. Since lighting in the field of the visual task primarily needs to meet visual requirements, is is not advisable to plan additional lighting providing biological impacts in this part. If we consider that the sensitivity of photoreceptors for biological light effects is higher in the lower area



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Infobox on biological impact

To achieve an optimal biological impact, the following illuminance levels and colour temperatures are recommended.

Encouraging concentration and alertness during the day
- Keep illuminance between 300 and 500 lx on the eye throughout the entire work day
- The lighting level should be equal to daylight quality
- Until the early afternoon, the colour temperature should be at least 5,500 K

Please note:
Individually designed light management systems with application-specific sensor technology can contribute significantly towards minimizing the energy demand of an HCL solution.

- The use of only warm white light combined with daylight during the day creates inappropriate lighting moods. During daytime, at least neutral white light colours should be used.

At the end of the day
- Reduce biologically effective blue components to a minimum
- Use warm white light with 2,700 K or a maximum of 3,000 K. Even for standard illuminance levels with the aim of performing visual tasks, this is a good compromise between a good quality of vision and not too strong biological impact.

11

Definition: Extract from DIN SPEC 5031-100
The conversion value $m_{v,\,mel,\,D65}$ enables a direct conversion of the photopically rated photometric value according to V(λ) to the appropriate melanopical rated value.

Light source	Conversion value $m_{v,\,mel,\,D65}$ (depends on the light source spectrum)	Example for illuminance on the eye	Melanopically rated illuminance level on the eye
LED, 2.700 K	0,41	50 lx	20 lx
LED, 4.000 K	0,63	380 lx	240 lx
LED, 6.500 K	0,80	300 lx	240 lx
Fluorescent lamp, 8.000 K	0,96	250 lx	240 lx

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of the retina (image 9), a range of about -15° to +45° results in the horizontal field of view, whereby biologically effective light has the highest efficiency. In smaller spaces or when the view goes towards a forest, they form a useful surface to be illuminated as a secondary light source. To achieve this, the walls must be of a light colour and able to reflect light diffusely. It is important to keep in mind that each surface in a room that reflects light, also has an influence on the light spectrum. In larger rooms or when the walls cannot be used, the ceilings of the room represent a useable space.

When using bright surfaces, visible luminance levels should not exceed values between 500 and 1,000 cd/m^2 to avoid risk of glare. Bright surfaces should therefore be as large as possible to be able to reflect sufficient light even without a high luminance level.

One thing, however, is important: Avoid direct light on people to avoid dazzling them.

Spectrum
Given the same illuminance level, “cold white” light with a high colour temperature has a stronger effect on the biological system, as it has a higher proportion in the melanopically effective blue range than warm white light. The spectrum of activity for melantopic light effects $S_{mel}(\lambda)$ describes the relation between the light spectrum and biological effect (see also DIN SPEC 5031-100).

Illumination and spectral distribution determine together the effectiveness. DIN SPEC 5031-100 defines a conversion factor, allowing conversion of the photopically rated photometric value to the melanopical rated value (see table/illustration 12).

Synchronising day-night rhythm
To synchronise our day-night rhythm, we need to provide sufficient stimulation for the biological system in the morning. It is important that the biologically active light level is higher than the light that is absorbed in the afternoon or evening.
If the melantopic lighting level remains low during the day, a higher melantopic lighting level in the evening can result in a disturbance of the circadian system. Illuminances between 300 to 500 lx at the eye with a light colour similar to daylight for a few hours in the morning are sufficient to synchronise circadian rhythm. The higher the risk and the level of disturbing lighting in the evening, the higher the stabilising light level needs to be in the morning (see also DIN SPEC 67600).

Activating lighting
Lighting that activates and encourages performance and concentration requires higher illuminance levels. In some studies, this was achieved very quickly by providing illuminance levels between 1,000 to 2.000 lx. However, such illuminance levels stand in the way of the requirements for a reasonable use of energy. Energy consumption can in turn be influenced positively by means of an appropriate light management system. Within about 20 mi-

[10] Depiction of ideal incidence of light of biologically effective light.

[11] Recommendation on illuminance levels and colour temperatures to achieve optimal biological effect.

[12] The tables show a factor to convert photopically rated values to melantopically rated values.

nutes, the activating effect of light can be felt. After another approximately 20 minutes, when the illuminance level is reduced, the effect abates. The activating effect should be limited to fixed number of times a day, on the one hand to avoid a habituation effect, on the other hand to keep the energy requirement to a minimum.

Lighting at the end of the day/to relax
At the end of the day, the lighting should have as little effect on the biological system as possible. It is recommended to switch to low illuminance levels on the eye two hours before going to bed. Lighting should be focused on the visual task only and – as far as required to provide visual comfort – the surroundings should be illuminated as bright as required by relevant standards for good vision, while reducing the biologically effective blue components to a minimum. Warm white light a colour temperature between 2,700 K and 3.000 K provides a good compromise with a high quality of vision.

“Prolonged days” and shift work
The “right lighting at the right time” refers to a “typical” everyday working life of people working during the day, as is reflected in many cases – whether at work in a typical office or in industrial production during the day, in the case of many pupils or students or work in the domestic field. In these cases, one can orient towards the average course of natural daylight to answer the question for the “right” light. Humans have developed through evolution in a natural lighting environment with an average of 12 hours of daylight and 12 hours of darkness. This rhythm provides a natural and thus healthy basis for artificial lighting as a point of reference. It is definitely acceptable to extend short days in our northern hemisphere in the winter by means of artificial lighting towards a desired length of day, which is conducive to our health. An example: At school, classes generally start at 8 o’clock during all seasons. One the one hand, it is known that this is too early for many pupils and their circadian rhythm. On the other hand, the start of classes does not consider the seasonal variations in our individual rhythm. In wintertime for example, as the natural light pulse is missing in the morning, artificial lighting can replace this impulse to accelerate waking up in the morning. The natural changes throughout the course of the day can be used to facilitate work in workplaces like supermarkets with long opening hours in the evening, hospitals or police offices.

Recommendations

In order for artificial light to exert the desired non-visual, biological effect, certain minimum values for the melanopically rated illuminance level on the eye should be obtained. Details of this assessment are laid down in DIN SPEC 5031-100. For fluorescent lamps with a colour temperature of 8,000 K, a (photometric) minimum illuminance level on the eye of 240 lx is recommended. For LED with 6,500 K, an illuminance level of at least 300 lx should be achieved. With lower colour temperatures, the (photometric) minimum illuminance level would be higher; e.g. 380 lx on the eye for a light source with 4,000 K. Conversely, certain maximum values should not be exceeded, if the aim is to keep the melanopic effects at a low level. In this case, 50 lx on the eye at 2,700 K should not be exceeded.

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Comments on night shifts
Approximately 15 percent of employees work regularly at night, up to 25 percent occasionally. For this group, it is not easy to recommend the right lighting at the right time. Three-shift systems with night shifts are particularly difficult where they are based on a periodic rotation of shifts. It must be assumed that such a rotation disrupts the circadian system to such a considerable degree that adjusting the internal clock to working times becomes impossible even with specific lighting.

Two-shift systems where the rotation happens between morning and evening shift, however, can be supported with appropriate lighting. The circadian rhythm can be varied by about two to three hours per day using specific lighting. As shifts usually rotate after two or three days to the later shift, synchronising the light in a three-shift system is not possible. Therefore, cold white lighting similar to daylight during night shift causes disruptions to day-night rhythm. Scientists therefore recommend synchronising the circadian system as closely as possible with the natural external day-night rhythm even when working in rotating shifts. This can be achieved by using lighting with high blue components during the day and low blue components at night for shiftworkers. Sufficient brightness during the night shift must ensure good eyesight and prevent fatigue. The question of the ideal brightness levels and colour temperatures is the subject of current research projects.

Scientists share the opinion that neither a static “standard lighting” for day and night shifts nor bright lighting similar to daylight for night shifts are appropriate for rotating shift work. However, further research is needed on this issue, and the recommendations set out here cannot yet be considered as generally accepted. Lighting for workplaces with rotating shift work should always be planned with the representatives of the affected employees, the local health management and authorities responsible for occupational health and safety, taking into account the specific circumstances.

Infobox evening and night shift

Research into the effects of light with regard to shift work are still ongoing. Scientists currently recommend the following aspects:

- Light colours and illuminance levels that are desireable and useful during the day, may cause disruptions of the day-night rhythm when used at night. Conversely, lighting scenarios suitable for evening and night shifts are usually not suitable for use during the day. Therefore, it is useful to use light management systems that allow switching between day-time and night-time lighting.
- Preventing daylight-white lighting at night, if no permanent shift of the circadian system is possible (where required in cases of permanent night shifts, when night turns into day on a permanent basis).
- Using warm white light colours in the evening and at night at high illuminance levels.

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[13] Recommendation for the melanopically rated illumination level on the eye.

[14] It has not yet been fully researched what effect light exerts on shift workers, however, it is possible to make recommendations on the use of lighting.

Four application examples

Some exemplary applications of HCL solutions are discussed below.

The fundamental procedure follows the so-called lighting system design process. The process starts with a need analysis where the light designer examines the specific needs and requirements of the user. The designer analyses the visual tasks to be performed at the workplace such as concentration, communication, computer work, detail work, workshop scenarios etc. and examines the areas where these tasks are performed, while taking into consideration the time of day and the person performing them. In this context, it is important to know about the technical equipment, flexibility of workplaces as well as ergonomic and health aspects. What forms of a lighting concept are appropriate for the particular working situation and thus within the respective working and living environment? In the holistic approach to the system of workplaces, light is increasingly becoming an important component.

For every project, the regulatory standard maintenance values for illuminance levels and other lighting criteria (see page 19, “Values for the effect of light according to the HCL concept”) are to be observed to meet the requirements for visual comfort and visual performance. Thus, the visual requirements for fulfilling the tasks assigned are met.

The lighting is designed in such a way that it covers architectural, formally aesthetic and perception psychology aspects and supports our well-being. This is how the emotional effects are taken into account. The design assumes that lighting can occur by using daylight, artificial light or a combination of the two (DIN EN 12464-1).

The natural course of daylight is considered ideal and forms the reference of our understanding of light quality. The spectral composition, brightness and direction of light vary over time. Lighting solutions and light management concepts should therefore reflect our daily rhythm as far as possible in order to ensure a full biological effect.

Exemplary basic rules are the following: From the morning to the early afternoon, the circadian rhythm of humans is simulated with daylight at a high illuminance level. On the other hand, in the evening and at night, disruptions of the circadian rhythm are to be avoided or at least to be minimized by using warm white light colours and lower illuminance levels. Lighting scenes during the day are determined by large-surface lighting provided by luminaires or reflected from ceilings and walls, while direct light and point lighting is used in the evening. The tasks of the technical planner include providing background information (see fact sheet on page 18) in order to enable users to use lighting properly. This includes recommendations on how to use light, for example in flexitime or on open-plan office scenarios. A fact sheet explains lighting features on the one hand and the effects of the lighting solution on the other.

Dynamics of light on each day and depending on the season
Users can select individual light moods actively or they run automatically. In areas that are used by several people automatic sequences are often most effective. Operation of the lighting is performed in one central location in the room or individually via smartphone. Another option are switches for simple selection of light scenes.

The lighting concept leads to the selection of luminaires and their arrangement and to an operational concept. It is displayed as a ground plan for the interior design. A light panel shows the selection of light scenes.

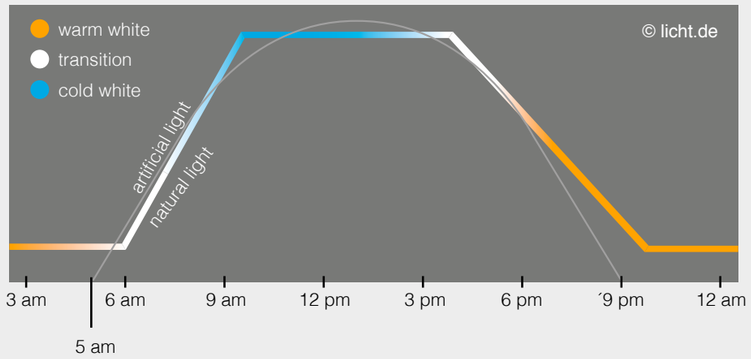
Individually designed light management systems with application-specific sensor technology can make an important contribution towards minimizing the energy demand of an HCL solution.

Natural course of daylight and course of light of an HCL solution
The following two examples show the natural course of daylight in the summer (image above) and in the winter (image below). The second graph shows a basic solution for the artificial course of daylight in accordance with the HCL approach.

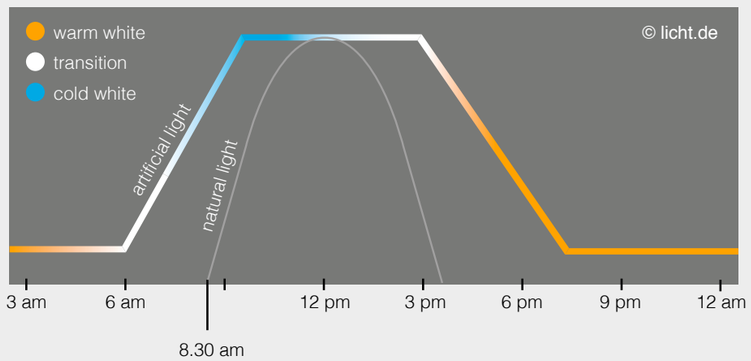
In the summer, the graph of artificial course of daylight runs along the natural course of daylight. In winter, on the other hand, it prolongs the day. Here, the artificial lighting reflects the natural length of day that is healthy for humans.

In the examples on the following pages, the graph was adjusted to the requirements of each scenario.

Example: Summertime



Example: Wintertime



Definitions regarding the following application examples

$\bar{E}_h$: average maintained horizontal illuminance, in the area of the visual task

$\bar{E}_v$: average maintained vertical illuminance, on the walls and on the blackboard

$\bar{E}_Z$: average maintained cylindrical illuminance

$\bar{E}_{Eye}$: maintained illuminance on the eye, typically vertical

Office

Modern office concepts are increasingly determined by digital network technologies and the idea of working globally 24/7. This results in flexible working hours in the office, ranging from early in the morning to late in the evening, and a wide range of activities. Hence, it is no surprise that the equipment level of modern office spaces is increasingly geared towards ergonomic aspects and acceptance and well-being. This is where an HCL lighting concept has a positive impact on the employees.
The example is designed for an office with two workers, with an occupancy time between 7 a.m. to 8 p.m. It can also be applied to larger office spaces (multi-person or open-plan office). In this case, walls become less dominant, whereas ceilings and objects in the room become more important.

Requirements for the workspace
Modern space concepts construe the office forms in a new way: Today, the office is generally regarded as a living environment offering areas for working, communicating and recreation. Lighting must meet the requirements both for a good visual performance and job satisfaction. At the same time, it is a means of creating spaces using furniture, acoustics and communication technology. New flexible space concepts require flexible solutions featuring dynamic light and high-quality lighting. They must be regulated when required. The following requirements have to be met:

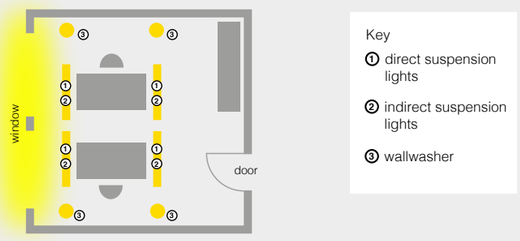
- Visual tasks, concentration, communication, computer work
- Flexible arrangement of workplaces
- Light as part of the workplace system
- Ergonomics and health
- Adjusting the lighting to time of day and year
- Adjusting the lighting to user's individual needs

Impact of light
Visual
- Requirements to the illuminance according to DIN EN 12464-1
  a: In the areas of the visual tasks
  b: On the walls and ceilings
  c: Cylindric illuminance in the room

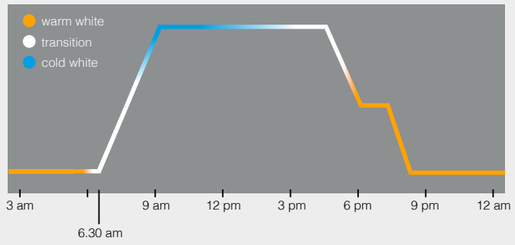
Emotional
- Engineering the working environment with daylight and artificial light
- Attractive choice and arrangement of luminaires

Biological
- Spectral proportions at specific times on the eye of the user to support the biological rhythm in the best possible way
- Biologically effective illuminances throughout the day to support activity and productivity in the best possible way

Interior space design



Daylight automation long-term operation



Design

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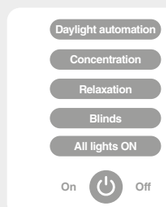
Visual
- $\bar{E}_h$: 500 lx ① + ②
- E_Z: 200-300 lx ① + ②

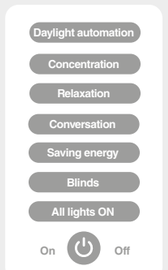
Emotional
- $\bar{E}_v$: 200-300 lx ② + ③
- Relax ② + ③

Biological
① + ② + ③
- $\bar{E}_h$: 800-1.000 lx
- E_{Eye}: 250 lx

Light scenarios
Control unit at the entrance:



Control unit smartphone, in addition to the above scenarios:



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Fact sheet on your HCL lighting at the office

The aim of this fact sheet is to give you an understanding of the impact and operation of lighting installations.

Light has various effects and it always works – visually, emotionally and biologically.
Human **C**entric **L**ighting (HCL) has a specific long-term effect on our health, well-being and on the productivity of any human being through holistic planning and implementation of the visual, emotional and particularly biological impacts of light. By modifying the light colour and illumination level, the HCL light solution guides you throughout your day, helps you to do your work more easily or relax when necessary, all by allowing you to choose "your light".

But don't forget: Try to spend at least 30 minutes in natural daylight!

1) Operating the lighting
a) Next to the entrance door is a switch you can use to set four light scenarios.
- Daylight automation: smooth change of light mood throughout the day and year according to incoming daylight
- Bright working light for concentration (only for short periods, not after 10 PM)
- Light during the break for relaxation
- Blinds: manual opening/closing

You can operate the blinds manually at any time. When exposed to sunlight, the blind is closed to prevent glare and overheating.

b) The room is fitted with direct and indirect luminaires, with the indirect luminaires determining an automatic daily routine and the direct luminaires providing standard-conforming work light. This can be overridden using switch functions of the luminaire (e.g. expansion feature). The light is dimmable.
c) You can also control the light at your workplace using your smartphone (add here information on download address: http:// ...). This way you can define additional light scenarios.

2) Use of lighting
The lighting creates the best possible conditions for the office work. By changing smoothly throughout the time of day and year, it supports your well-being. Furthermore, you can design to use "your light". Your work will become easier.

For further questions, please contact us by phone at (0123) XXXXXX.

Light design concept
- Room illumination, spatial brightness distribution of light densities [cd/m2] and light intensity [lx]
- Illumination of the workplace: identify visual tasks, disturbance-free vision, supporting visual performance and visual comfort (DIN EN 12464-1)
- Cylindrical illuminance levels for better communication and perception of space
- Illumination of walls and ceilings to prevent cave effects
- Lighting accents for emotional light moods
- Ideal colour rendering of materials and surfaces
- Sufficient vertical illuminance on the eye
- Preset dynamic processes oriented on the course of daylight
- Preset scenarios
- Manual setting option for employees (higher illuminance for challenging visual tasks and for older employees)
- Flexible adaptation of direct components for height-adjustable desks
- Integrating daylight and using different blind positions

Luminaires and control
Selection criteria for luminaires:
- Suspension lights, direct/indirect light distribution, for the assigned workplace lighting
- Wide-angled surface luminaire with indirect ceiling lighting to support the cylindrical lighting in the room
- Sufficient direct lighting portion for the working plane
- Positioning direct lighting portions free of reflective glare
- Vertical illumination on walls by means of wallwashers, bright room impression
- Wallwasher and suspension lights – with colour temperature variation = tunable white (warm-white – daylight white)
- Vertical illumination on the eye

Variations are possible:
Characteristics within a luminaire or distributed over several luminaires

Control features
Control circuits:
- Two suspension lights per workplace
- Direct and indirect components can be controlled separately, each with adjustable white colours
- Blinds

Input:
- Daylight sensor
- Motion sensor
- Utility
- Control unit

Automatic controller:
- Programming is based on daylight curve throughout the year. In winter, the daylight intensity is extended in the morning and evening. This affects the indirect component of suspension lights and wallwashers.
- In addition, the indirect component is adjusted to the incoming daylight via a daylight sensor.
- The direct component of the suspension light is switched on in presence via a motion sensor.

Light scenarios
- All lights ON: all luminaires 100%
- Concentration: mainly direct components, indirect reduced by 50%
- Conversation: balanced share of direct/indirect components, consistent wall brightness
- Relaxation: direct and indirect reduced by 20%, mainly wallwasher, dimmed in different ways
- Energy saving: only indirect components, follows daylight automation, direct components are dependent on motion and daylight (constant illuminance)
- Sun protection concept (blinds) is to be aligned with the HCL lighting concept.

Operating the lighting
The control unit allows the selection of light scenarios, overwriting the automatic mechanism. Note: The system must allow stepping in at the right place of the automatic lighting course after stopping the automatic mechanism.

One control unit is mounted at the entrance. Further light moods can be selected via smartphone:

Control unit at the entrance:
- Daylight automation
- Concentration
- Relaxation
- Blinds
- All lights ON

Control unit smartphone, in addition to the above scenarios:
- Conversation
- Saving energy

School

Anyone who learns and studies needs good light, as it supports the learning results. Students sit not only at the table, they also hold presentations, communicate and discuss. They write exams, but they also require recreation in between.

However, many pupils are still half asleep in the morning, as the school timetable ticks different to the internal clock of the students. Many young students are often wide awake late in the evening, but have difficulties getting up in the morning and have little motivation to learn; they are in a “social jetlag”.

The example is designed for a classroom of a higher secondary school with evening classes, with classes starting at 8 o’clock in the morning and finishing around 9 o’clock in the evening.

Classroom requirements
Students constantly face certain learning situations. The better the light is adjusted to those learning situations, the more information can be absorbed, processed and stored. Good light motivates them and helps to stay focused for longer periods. A balanced illumination situation creates ideal learing conditions. The following requirements must be met:

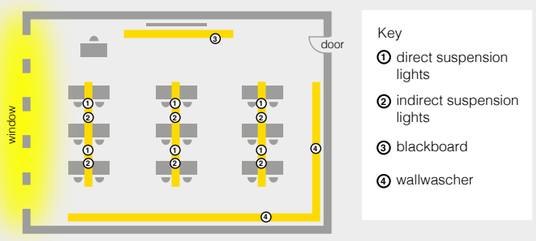
- Studying, reading, listening (presentation, projector, exercises)
- Interactive tasks, with or without new media like tablets
- Flexible table arrangement
- Presentations held by the pupils
- Equal learning environment at each time of the day and year
- Group and individual work

Impact of light
Visual
- Illuminance according to DIN EN 12464
  a: In the areas of the visual tasks
  b: On the walls and ceilings
  c: Cylindric illuminance in the room

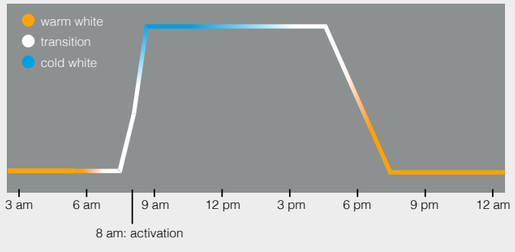
Emotional
- Various lighting moods
- Optimal work support through the lighting solution (activating/soothing)
- Engineering the working environment with daylight and artificial light
- Attractive light moods

Biological
- Spectral proportions at specific times on the eye of the user to support the biological rhythm in the best possible way
- Biologically effective illuminances throughout the day to support activity and productivity in the best possible way

Interior space design



Daylight automation long-term operation



Design

Visual
- $\bar{E}_h$: 300-500 lx ① + ②
- $\bar{E}_v$: 500 lx (blackboard and walls) ③ + ④
- E_Z: 200-300 lx

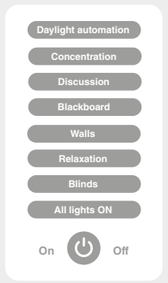
Emotional
- $\bar{E}_v$: 200 lx ② + ④

Biological
① + ② + ④
- $\bar{E}_h$: 800-1.000 lx
- E_{Eye}: 250 lx

Light scenarios

Control unit at the entrance:

One additional control unit at the teacher’s desk:



Fact sheet on your HCL lighting at school

The aim of this fact sheet is to give you an understanding of the impact and operation of lighting installations.

Light has various effects and it always works – visually, emotionally and biologically.
Human **C**entric **L**ighting (HCL) has a specific long-term effect on our health, well-being and on the productivity of any human being through holistic planning and implementation of the visual, emotional and particularly biological impacts of light. By modifying the light colour and illumination level, the HCL light solution guides you throughout your day, helps you to do your work more easily or relax when necessary, all by allowing you to choose “your light”.

But don’t forget: Try to spend at least 30 minutes in natural daylight!

1) Operating the lighting
a) Next to the entrance door is a switch you can use to set four light scenarios:
- Daylight automation
- Discussion: bright light, motivating
- Walls: illuminated wall surfaces, dimmed general lighting
- Blinds: manual opening and closing

b) At the teacher’s desk is another light tray you can use to select further lighting scenrios:
- Daylight automation
- Concentration: more light on the tables, e.g. during tests
- Discussion: bright light, motivating
- Blackboard: illuminated blackboard; slightly reduced, rather indirect room light
- Walls: illuminated wall surfaces, dimmed general lighting
- Relaxation: dimmed calm light atmosphere
- Blinds: manual opening and closing
- All light ON

You can operate the blinds manually at any time. When exposed to sunlight, the blind is closed to prevent glare and overheating.

2) Use of lighting
The lighting creates the best possible conditions for the school. By changing smoothly throughout the time of day and year, it supports the well-being. Furthermore, teachers and students can decide to use “Your light”. Working and learning will become easier.

For further questions, please contact us by phone at (0123) XXXXXX.

Light design concept
- Blackboard – writing/reading (DIN EN 12464) – vertical illuminance
- Projector/whiteboard
- Tables – reading (DIN EN 12464-1) – horizontal illuminance
- Walls (pinboard) – vertical illuminance
- Teacher (recognition of face/facial expressions)
- Group work/communicate (cylindrical values)
- Perform handicraft work
- Follow presentations on the projector as fatigue-free as possible
- Tablet/computer without irritating reflections
- Activating in the morning at the start of classes (optional) – planar light
- Calming down/relaxing depending on the situation
- Intuitive operation through teachers and pupils
- Scenario control (door – easy)
- Scenario control (teacher – complex)

Luminaires and control
Selection criteria for luminaires:
- Suspension lights, direct/indirect light distribution
- Wide-angled glare-free direct light component to support cylindrical illumination in the room
- Indirect ceiling lighting
- Blackboard lighting
- Illuminating wall surfaces (surfaces for posters and pictures)
- Vertical illumination – projector/whiteboard: specifically hide projection screen/wall
- And wallwashers with colour temperature variation = tunable white (warm-white – daylight white)

Control features
Control circuits:
- Direct and indirect components can be controlled separately for all suspension lights, each adjustable white
- Blackboard lighting
- Wallwasher, tunable white
- Blinds

input:
- Daylight sensor
- Utility
- Motion sensor
- Control unit

Automatic controller:
- Programming is based on daylight curve throughout the year. In winter, the daylight intensity is extended in the morning and evening.
  → Affects the indirect component of suspension lights and wallwashers.
- In addition, the indirect component is adjusted to the incoming daylight via a daylight sensor.
- The direct component of the suspension lights is switched on in presence via a motion sensor.

Light scenarios
- All lights ON: all luminaires 100%
- Focus: mainly direct component, indirect reduced by 50%
- Discussion: high indirect component, direct component reduced, average wall light
- Blackboard
- All walls
- Relaxation: only indirect by 50%, walls 30%

Operating the light
You can use the control unit to select different light scenarios, overwriting the automatic mechanism.

One control unit by the door:
- Daylight automation
- Discussion
- Walls
- Blinds
- All lights ON

One additional control unit at the teacher’s desk:
- Concentration
- Discussion
- Blackboard
- Walls
- Relaxation
- Blinds
- All lights ON

[15] The image shows an example for an HCL lighting concept, including interior design and parametres for the design and operation at the office.

[16] An HCL lighting concept can have a positive effect on the well-being, motivation and concentration of the students even at schools.

Industry

Existing lighting systems for industrial applications are generally planned in accordance with older lighting standards. However, the standards of light quality at industrial workplaces has changed over time. New dynamic lighting systems in industrial companies show that biologically effective lighting has multiple positive effects:

- The well-being in day-to-day operations increases just as the sleeping quality at night.
- The focus is retained and thus also safety at work.
- The employees are more motivated, and an ergonomic workplace is supported.

The example is designed for an assembly area with typical assembly workplaces and break room for early, day and late shift work. Night shift work is not considered in this example.

Requirements concerning assembly area
Highly specific work assignments on the one hand and a high degree of automation on the other are the general rule. The following requirements should be met in the various premises:

Assembly workplace
- Concentrated viewing and working
- Equal working conditions at each time of the day and year
- Illuminating the workplaces to ensure accident-free assembly, illumination further contributes to a relaxing atmosphere in the break rooms
- Light as an instrument to support individual requirements/processes

Hall
- Securing traffic routes
- Consistent illumination of the working areas
- Biological performance of the assigned visual tasks (DIN EN 12464-1)
- Safety issues (hazard identification)
- Light as a means to provide space for the workplace (safety, well-being)

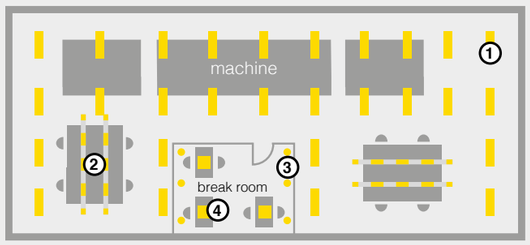
Break-time area
- Pleasant atmosphere
- Relaxation area (no stimulating area)
- Recreation

Impact of light
Visual
- Illuminance according to DIN EN 12464
  a: In the visual task areas
  b: Partly cylindrical illuminance in the room

Emotional
- Engineering the working environment with daylight and artificial light
- Optimal work support through the lighting solution (activating/soothing)
- Activating effect in the break room, use of daylight

Biological
- Spectral proportions at specific times on the user's eye to support the biological rhythmin the best possible way
- Biologically effective illuminances throughout the day to support activity and productivity

Interior space design



Key
① hall illumination
② light strips
③ directional light
④ wide-angled surface luminaires

Design

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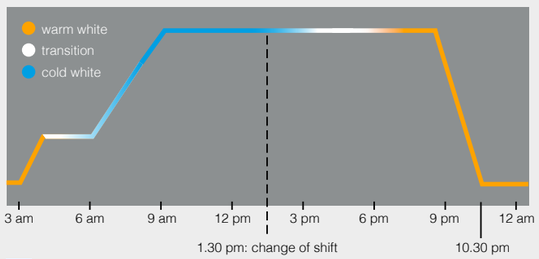
Visual
- $\bar{E}_h$: 500-1.000 lx ① + ②
- E_Z: 200-300 lx ① + ②

Emotional
- $\bar{E}_v$: 200 lx

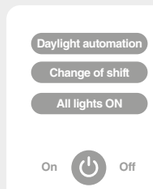
Biological (during the day)
- $\bar{E}_h$: 800-1.000 lx
- E_{Eye}: 250 lx

Daylight automation long-term operation

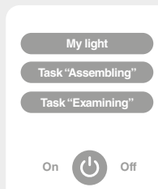


Light scenarios

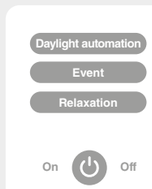
One control unit operated by the production manager:



Control unit at the workplace:



Control unit in the break room:



17

Fact sheet on your HCL lighting

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Light has various effects and it always works – visually, emotionally and biologically.
Human **C**entric **L**ighting (HCL) has a specific long-term effect on our health, well-being and on the productivity of any human being through holistic planning and implementation of the visual, emotional and particularly biological impacts of light. By modifying the light colour and illumination level, the HCL light solution guides you throughout your day, helps you to do your work more easily or relax when necessary, all by allowing you to choose "your light".

But don't forget: Try to spend at least 30 minutes in natural daylight!

1) Operating the lighting
The room lighting provides automatic sequences.

a) In the office of the production manager for the entire hall lighting:
- Daylight automation: smooth change of light mood throughout the day and year in harmony with the incoming daylight
- Change of shift: atmospheric lighting supports the change
- All lights on

b) At the workplace:
- My light
- Task "Assembling"
- Task "Examining"

c) In the break room:
- Daylight automation: smooth change of light mood throughout the day and year in harmony with the incoming daylight
- Event: Atmospheric light for small celebrations
- Relax: Colour of light and moods for break times

The user can only customise the individual lighting specifically assigned to the workplace to their individual needs. This light is controlled individually from the workplace. A relaxing light atmosphere prevails in the breakrooms.

2) Use of lighting
The lighting creates the best conditions at industrial workplaces and supports the user's circadian rhythm and well-being by changing smoothly throughout the time of day and year. Employees find it easier to work, and there is increase in concentration. The light is customised precisely to every work shift. At night, it is advisable to achieve as little activating light effect as possible. The best way to ensure this is to use a light colour with ≤ 3.000 K. In the break time areas, relaxation and recreation are most important.

For further questions, please contact us by phone at (0123) XXXXXX.

Light Design Concept
- Standard-conforming illumination of traffic routes (DIN EN 12464-1)
- Illuminating workplaces for accident-free work (observe ASR)
- Highlighting possible danger zones
- Use of glare-free lighting
- Well-balanced contrasts (not too high, not too low)
- Dividing the room into zones
- Arranging flexible workplaces
- Observing DIN SPEC 67600
- Activation, analogue to the working phase (adapted to early and late shift)
- After the breaeks (lots of light and a high blue content for improved concentration)
- Reducing the activating light components towards the evening (lower illuminance and significant reduction of blue content)

Luminaires and control
Selection criteria for luminaires:
- Horizontal – traffic routes: strip light, illumination of halls, observe degree of protection at high emissions
- Horizontal – work areas: strip light, illumination of halls, observe degree of protection at high emissions
- Cylindrical in the break room: wide-angled surface luminaires
- Pleasant atmosphere (arouse emotions in the break room similar to spa areas or private living environments, warm white light, e.g. 2,700 K)
- Directional light to detect surface textures: spotlight
- Changes in colour temperature = tunable white (warm white – daylight white)
- Energy efficiency (independent of day light and motion-dependent control)

Variations are possible: characteristics within a luminaire or spread over several lights

Control features
Control circuits:
- Area-based assignment
- in the break room: groups

Input:
- Daylight sensor
- Utility
- Motion sensor
- Control device

Automatic controller:
- Programming is based on daylight curve throughout the year, aligned with the working hours.
- Motion sensors at temporarily used work spaces and in the break room
- Further options:
- Preset scenarios (e.g. reduction of blue components at the end of the shift, and activation at start of the work)
- Customising preset user-specific light scenes to be carried out only by an assigned specialist
- Task-related manual setting option for the employee (higher illuminance levels for demanding visual tasks and older employees)
- Energy efficiency/energy saving if possible
- Use of daylight
- Data management/usage analysis to optimise processes and lighting solutions

Light scenarios
- All lights on
- On/off: at each workplace
- Pause: according to the time of day
- Colour of light and mood
- Optional: change of shift: dynamic change of light

Light operation
The control unit allows the selection of light scenarios, overwriting the automatic mechanism.

One control unit operated by the production manager:
- Daylight automation
- Change of shift
- All lights on

Control unit at the workplace:
- My light (customized work light)
- Task "Assembling"
- Task "Examining"
- Control unit in the break room
- Daylight automation
- Event
- Relax

Home

The key for sense of well-being in your home is the right light at the right time. Those who sit in front of a computer screen in the evening, may not sleep well, as the screen light has a high proportion of blue light, which has a stimulating effect. Meanwhile, there are utilities adjusting warm-white background lighting for the screen in the evening. It would be more advantageous to be exposed to more relaxing warm-white light in the evening. Intense cold-white light in the morning helps us wake up and start the day faster. Dynamic lighting helps to individually control and positively influence our individual sleep-wake rhythm by using different lamps and lights. People differ from one another in their chronotypes. If individual lighting scenarios are possible, the chronotypes can have their very own light variations.

The example has been worked out for a flat with several rooms, kitchen, bathroom and corridor.

Requirements for the home
Eating, reading, watching TV, working or relaxing – lighting needs above all to respond to various needs to in your own home. It is therefore important to be aware of the requirements for the different rooms and to implement them in a lighting concept. The following requirements should be taken into account:

Bedroom
- Sleeping
- Reading at different times
- Getting dressed/select clothing
- Mood lighting
- Daylight white wake-up light

Bathroom
- Washing/beauty care
- Use: in the morning, in the evening, at night

Kitchen
- Eating in a comfortable atmosphere/ quick breakfast
- Preparing meals
- Playing
- Reading the newspaper
- Communication

Workroom
- Reading and writing texts (see office)
- Working at the computer and with other electronic media

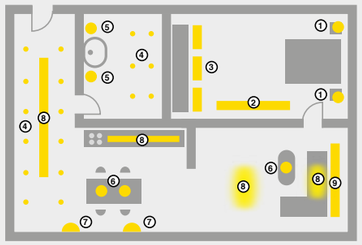
Living room
- Watching TV
- Being together
- Reading
- Playing

Impact of light
Visual
- Illuminance in the areas of visual tasks, safety aspects

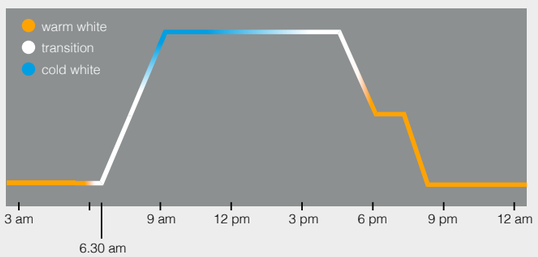
Emotional
- Creative light design/presenting home furnishings/pools of light

Biological
- Spectral proportions and biologicially effective/ineffective illuminance at defined times at the eye of the user

Interior space design



Long-term operation



Design

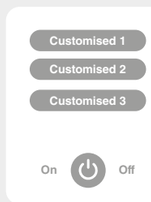
Visual Individual for visual task

Emotional customised

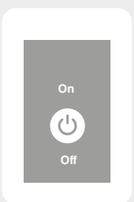
Biological E_{Eye}: 250 lx
Otherwise customised, lower illuminance in the evening (only warm white)

Light scenarios

One control unit per room:



Operation via smartphone:



Fact sheet on your HCL lighting

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Human Centric Lighting (HCL) has a specific long-term effect on our health, well-being and on the productivity of any human being through holistic planning and implementation of the visual, emotional and particularly biological impacts of light.

By modifying the light colour and illumination level, the HCL light solution guides you throughout your day, helps you to do your work more easily or relax when necessary, all by allowing you to choose "your light".

But don't forget: Try to spend at least 30 minutes in natural daylight!

1) Operating the lighting
The room lighting provides automatic sequences.

a) In the corridor
- All lights: On/Off

b) In the kitchen
- All lights: On/Off
- Cooking
- Dining
- Celebrating

c) In the living room
- All lights: On/Off
- Reading
- Watching TV
- Relaxing
- Celebrating

d) In the bedroom
- All lights: On/Off
- Getting dressed
- Reading
- Cuddling

e) In the bathroom
- All lights: On/Off
- Putting on make-up and shaving
- Relaxing

f) Outdoor
- All lights: On/Off

2) Use of lighting
Lighting solutions create the best basis for your home – the decision about "Your light" lies in your own hands.

Design Concept
- Different lighting systems
- Emphasising/presenting the rooms
- Performing various visual tasks
- Providing vertical illuminance in the kitchen, bathroom, living room and in front of the wardrobe in the bedroom
- Light on the face in the mirror
- Controlling brightness and colours of lighting depending on the time of day
- In the evening and at night → Reducing the blue spectrum in order not to disturb the circadian rhythm

Lamps and control
Criteria for lamps:
- Various lighting systems
- Operation via button/switch or smartphone/remote control/voice control
- Bright, glare-free worklight to decorative light
- Supporting the natural course of daylight with regard to colour temperature and illuminance

Features of controllers
Control circuits:
- Spatial attribution

Input:
- Scheduler
- Motion sensor
- Control units per room

Automatic controllers:
- Programming is based on daylight curve throughout the year, aligned with the periods of motion.
- Motion sensors in less frequently used rooms

Light scenarios
- To be planned individually for each room

Operating the lighting
The control unit allows the selection of light scenarios, overwriting the automatic mechanism.

- One control unit per room
- Operation via smartphone

[17] An HCL lighting concept for industry applications must be tailored to meet the various needs.

[18] Whether in the morning when we get up, during dinner or while brushing the teeth – HCL lighting concepts for your home can increase your well-being.

Glossary

Biological light effects - Light always has a biological effect, just as it always enables visual perception. Therefore, we do not distinguish between biologically effective or visually effective lighting. Both aspects are inseparable.

Nevertheless, HCL lighting should be designed and operated with particular focus on biological light effects, just as the consideration for the guidelines for visual aspects.

The term “biological” effects of light used in this guide describes the non-visual effects on physiological and mental processes in humans. Despite the fact that the visual process is also a biological process, it serves to differentiate linguistically between visual and non-visual effects.

Blue components, colour temperature and their relation to biological effects - In the context of this guide, the term “blue components” is used as a synonym for the biologically effective radiation in the visible range. They lie primarily in the spectral range between 450 and 530 nm that humans visualise as blue and blue-green, with a maximum at 490 nm. Although the maximum sensitivity for visual perception of blue light with 450 nm is more in the short-wave range, the spectral proportions that are responsible for biological effects are frequently referred to as “blue component” or “blue light” due to the colour impression of the relevant light, although the light itself often appears white.

The term “blue component is furthermore frequently used in connection with possible retinal damages due to Blue Light Hazard. In both cases, the term is not fully correct, as the effect has nothing to do with the visual process of colour vision.

For ‘usual’ light sources as they are used for general lighting purposes, the blue component correlates directly with the colour temperature, at least within any light source category. In the range between 3,000 K and about 6,000 K, this correlation is almost linear. It is therefore appropriate to expect a higher blue content and thus stronger biological effects for cold white or daylight white lighting than for warm white lighting.

Blue Light Hazard - In this case, possible retinal damages caused by spectral components with a maximum sensitivity of 440 nm and a range of about 410 to 480 nm (half width) are meant, and at a very high spectral radiation density, the potentially damaging spectral components can extend into the red parts (e. g. laser pointer).

In general-purpose lighting applications, the risk of blue light hazards does not play a role. This fact is supported by a number of independent bodies and bodies in charge of industrial safety (e. g. LiTG, SCENIHR, DGUV). Just as relevant, the “preliminary opinion” published in July 2017 (Scientific Committee on Health, Environmental and Emerging Risks) of the scientific commission SCHEER, engaged by the European Commission to do a risk analysis Risikobewertung of LED.

The same applies to workplaces equipped with HCL lighting installation. Hence, no further consideration of this aspect is required in the context of Human Centric Lighting.

At specific workplaces where light acts as a working or testing equipment, a risk assessment with regard to photobiological safety is mandatory.

A separate assessment can be useful for the therapeutic use of very bright light sources (e.g. for the purpose of light therapy).

Chronotype - There are people who prefer to get up early and wake up without alarm clock. They achieve their maximum efficiency in the morning (early risers, larks). On the other hand, there are people who prefer to sleep longer, who often do not wake up without alarm clock. They often have difficulties start-up difficulties (late risers). They are often called owls, as they are often awake, active and productive until the late evening. Between those extreme types, there are many nuances in between.

The chronotype is an approach to quantify this characteristic. The chronotype has nothing to do with the sleep duration. The chronotype can be determined by means of questionnaires. A method for shift workers is the D-MEQ (German version of the “Morningness-Eveningness-Questionnaire”). Another questionnaire to determine the chronotype is the MCTQ (Munich Chronotype Questionnaire).

A healthy and restful sleep – as well as an appropriate performance in waking hours – is only possible when working and sleeping hours are in line with the chronotype. This requires the circadian rhythm to be resynchronised each and every day. Light is the strongest factor influencing this daily resynchronisation.

Circadian rhythm - A biological rhythm of about 24 hours (Latin: ‘circa’ meaning “approximately” and ’dies’ meaning “day”). Light is the most important cue for synchronising circadian rhythms. The most concise of these rhythms is the sleep-wake cycle. However, other rhythms such as eating or digesting, are easily recognisable circadian rhythms. Many other circadian rhythms in humans are not directly recognisable: body temperature, hormone levels and even respiration and circulation are governed by circadian rhythms that ultimately extend to the metabolic processes of each and every cell of the body. Synchronising these rhythms with the natural cycle of day and night is essential for human health. Light plays a decisive role in influencing the synchronisation.

Cortisol - hydrocortisone – is often referred to as “stress hormone” as it is released due to stress. It has a stimulating effect on various bodily functions and should rather be described as “activity hormone”. Without the increase of the cortisol level, it would be very hard for us to get up in the morning and activities would generally be more exhausting. The cortisol level is also governed by a circadian rhytm with its maximum in the morning.

Human Centric Lighting - The term “Human Centric Lighting” represents a lighting concept, considering equally visual aspects of perception and visual comfort and biological and emotional aspects (see also the definition to be found in the introduction on this guide or in the position paper on Human Centric Lighting provided by ZVEI). Since the year 2010, the term has been more frequently used and was further widely used in the publication of the study named “Going Beyond Energy Efficiency” conducted by the consulting firm A.T. Kearney in the year 2013. As the term was initially mainly used by the lighting industry, scientists often hesitated to adopt it. This is the main reason why the CIE introduced the term “integrative lighting” as a synonym. Both terms are equivalent.

Scientists often refer to the effects of light and then call it “non-visual effect” or “non-imaging effect” when they describe the effects of light beyond visual aspects. Visual and non-visual effects are rather infrequently dealt with simultaneously on a scientific level. Therefore, it makes sense to distinguish between these effects.

The Lighting Technology Technical Standards Committee (FNL 27) originally introduced the term “biologically effective lighting” in DIN V 5031-100 and DIN SPEC 5031-100. This term just like the term “non-visual” were initially intended as a delimitation of lighting geared towards visual aspects. It has, however, resulted in the fact that in day-to-day lighting practice both terms were viewed separately from each other. Meanwhile, it is generally accepted basic knowledge that each lighting solution exerts visual and non-visual (= biological) effects at any time.

Integrative Lighting - This term was introduced by the CIE as an alternative to Human Centric Lighting (see definition under Human Centric Lighting).

ipRGC, retinal ganglion cells, third photorezeptor - ipRGC is the abbreviation for intrinsic photosensitive retinal ganglion cells. Apart from the photoreceptors (cones and rods) that are necessary for our vision there are also ganglion cells in our retina. They pick up the signals from these photoreceptors and transmit them to the optic nerve. About two to three percent of all ganglion cells in the retina also contain the photopigment melanopsin. This makes themselves (intrinsically) photosensitive, in total only around 2,000 per eye. These cells transmit signals not only when they receive this information from other photoreceptors, but they also respond to light from within themselves. This reaction is the essential basis for non-visual effects of light on humans. IpRGC are always involved in the biological effects, even when some effects are also influenced by other photoreceptors.

Light colours - Apart from a few colour accents for decorative purposes, general lighting usually uses white light. White light can be described through its colour temperature (more precisely “correlated colour temperature”). The correlated colour temperature of a white light source corresponds to the temperature of a black body, the radiation of which has the same colour impression as the corresponding light source.

Warm white: Lower colour temperatures, generally around 3,000 K or lower. Below 2,500 K, the light appears rather in an orange-yellow or reddish tone, although it is “white” by definition.

Warm white light sources are preferred in a private domestic area or in spaces where the aim is to create a pleasant, relaxing atmosphere (restaurants, hotels etc.). In general, warm white light has lower impact than light with a higher colour temperature. For a standard LED with 3,000 K, it represents about one third of the effect of daylight with the same level of illuminance on the eye. Hence, for luminaires used for HCL solutions a lower biologically effective lighting is implemented using warm white light sources.

Neutral white: Colour temperatures in a range of around 4,000 K. It is the most common light colour for office and industrial lighting in Central Europe and appears much colder than warm white light with 3,000 K.

With similar brightness, luminaires with 4,000 K have approximately 50 percent of the effect of daylight on the biological system. English-speaking sources describe neutral white frequently as “cool white”. This entails the risk of confusion with the term “cold white”, which stands for higher colour temperatures.

Cold white: Rather vague term for colour temperatures above approximately 5,000 K. In the domestic field or in a restaurant, even luminaires with 4,000 K may appear relatively “cold”. The term should therefore be used with care. A more accurate definition is advisable.

Daylight white: They include light colours above 5,500 K. A typical daylight light colour has 6,500 K. Its colour impression is closest to standard illuminant D65, which is considered a standardised representation of daylight. For such cold light colours, the colour perception of the human eye cannot distinguish in ranges less than 500 K.

The biological effects come closest to natural daylight when using daylight white luminaires. Light from standard LEDs with 6,500 K has approximately 85% of the effect of standard illuminant D65.

Higher colour temperatures are generally experienced as being very unpleasant and unnatural, if they are used as the only source of light. Combined with direct or indirect lighting, the ceiling can be lightened with extremely cold-white light, without being perceived as disruptive, as long as the direct lighting provides less cold white light. This gives the impression of an artificial sky.

Light management - Human Centric Lighting is systematically connected with an intelligent light management system.

Modern lighting concepts like Human Centric Lighting emerge from user and application requirements, combining the design principles of visual, non-visual and emotional lighting quality. Technical planners, when entrusted with this task,

have to develop a suitable lighting solution in a responsible manner on the one hand, and on the other specify suitable light scenarios. Traditionally, describing the lighting solution will be the first step in the design process. This step explains the effects and functions of light in the desired space. In the course of the creative lighting system design process, the planner preferably creates various lighting scenarios that are important and useful for the planning principles.

For HCL applications this means the implementation of dynamic light scenarios with changing light colours, spatial light distribution and customized brightness levels throughout the day. The technical planner should of course further take into account individual lighting requests, allowing the user to activate them flexibly as needed. In addition, if daylight is sufficiently available through the construction, it should be integrated and used in the lighting concept, also in terms of energy.

At this point, the light designer must involve an electrical engineer for system integration, unless he has the required professional expertise himself. As an alternative, the project manager in charge has set up a team of specialists, combining in an integrated and interdisciplinary way the various technology trades in the building via suitable interfaces.

To implement HCL concepts, lighting and electrical industries and the IT sector provide a substantial repertoire of building automated systems with appropriate application software. Depending on the specification of the lighting scenarios to be implemented by the light designer and automation to be planned (or already existing) in the building, the electrical consultant has to select a suitable system.

Technologies such as Digital Addressable Lighting Interface (DALI), Digital Multiplex (DMX) or KNX have proven for a long time to be conventional wired light management systems. In the past few years, more and more systems on a wireless basis have been introduced (ZigBee, Bluetooth, Enocean, WiFi or LAN/Ethernet). In the near future, all electrically or independently functioning components of a building or in the public area will have a unique IP address and will have arrived in the world of IoT.

Fascinating, by all means complex, but very useful are compatible signal interfaces with the aim of linking different systems with each other. Solutions for HCL applications need to include first of all timer modules to allow a circadian daytime sequence to be run dynamically and fully automatically. To enable the programmer to start up the HCL system, the light designer needs to give him a clear briefing, for example on the question on the periods and specifications of light settings.

The performance strength of modern Light Management System, or short LMS, lies also in the use of intelligent sensor technology (e.g. environmental facilities data) and software. The use and application of a professional LMS is also a clear differentiator from competitors. It may come for example in the form of a lighting designed to meet the needs of HCL in the healthcare industry that creates not only a spatial experience and has a positive influence on humans by means of appropriate light scenes, but also enables energy savings and data analysis.

Light management systems, however, must above all remain controllable. During the conception phase, it is important for the system integrator to achieve this aim. A user-friendly control interface, for example by means of a logical app light scenarios, enables easy operation. Light management systems are essentially all extremely complex, however, intuitively operated controls will ensure user-friendliness.

LSDP – Lighting System Design Process - The so-called Lighting System Design Process (LSDP) is described in prEN TS 17165.

The lighting system design process is an iterative process. This guide describes the key design aspects for the process for good quality, energy-efficient and effective lighting systems for major projects in the service sector. The finished lighting system is to provide an efficient, effective and high-grade lighting that meets the users' expectations. The solution should include safety/emergency lighting on the basis of a risk analysis or in accordance with legislation that is determined during the consultation process. Under certain circumstances, the individual elements of this design process can also be used in smaller lighting concepts.

The complete lighting system design process supports the implementation of regulatory measures and the development of testing requirements. This ensures that the anticipated energy savings are met without compromising the necessary lighting conditions.

Melanopsin, melanopic effects - Melanopsin is a type of photopigment responsible for the light sensitivity of the retinal ganglion cells (ipRGC). Its highest sensitivity lies between 450 and 530 nm (half-width) with a maximum of 490 nm. By stimulating this dye molecule by means of light, the ipRGC sends out nerve signals that trigger biological light effects. Even though there are different subtypes of ipRGC gibt and, according to what we know today, the other photoreceptor cells in the retina contribute to the biological effects, melanopsin-containing ganglion cells contribute most to the biological effects of light. As biological effects are essentially based on the stimulation of melanopsin-containing ganglion cells, they are also referred to as melantopic effects. In this guide, we use the term "biological" effects.

Melatonin - Hormone that signals "night rest" to the human body and makes us feel tired. It is also referred to as the "sleep hormone". Produced from serotonin in the pineal gland and secreted during the night, it can be inhibited by exposure to light during the night.

During the day in a "normal" circadian rhythm, melantonin can basically not be detected in the blood. The activating effect of light during the day is thus a different process that has nothing to do with melatonin suppression at night.

As melatonin is the most important externally measured quantifier for the circadian phases of our inner clock, the melatonin suppressing effect is generally regarded as equal to the circadian effect, i.e. the biological effect of light on the inner clock.

Light that is able to suppress melatonin at night, can generally also trigger other biological effects (even during the day, for example activation), as the stimulation of melanopsin in the ipRGC is the basis of all these effects.

Serotonin - Neurotransmitter, or messenger substance, that carries signals between nerve cells and acts as a mood elevator. It is therefore often referred to as a "happiness hormone". Its production is stimulated by daylight. At night, serotonin is biochemically converted into melatonin by the pineal gland.

Daylight - The term is used herein to describe the light that prevails outdoors, yet in an area protected from direct sunlight. It refers in particular on the visible components (light) and ignores UV or infrared radiation. They shall have no meaning for the biological effects described herein and will therefore not be considered in connection with HCL. In contrast, direct sunlight shows UV and infrared components, which are relevant for human health. As UV and IR components may also entail health risks, this topic should be dealt with separately. Natural daylight is considered the light source that ensures the optimum supply of biologically effective components. To assess artificial lighting, standard illuminant D65 is chosen as reference light the biologically effective spectral components refer to.

Please see DIN SPEC 5031-100 and CEN TR 16791 for further details. An important question remains whether the blue part of the spectrum contained in natural daylight can pass through the windows in modern buildings equipped with insulating solar protection glazing, in order to achieve the desired biological effect. A room supposedly well flooded with daylight might contain less biologically effective blue components than a similar room with artificial light similar to daylight.

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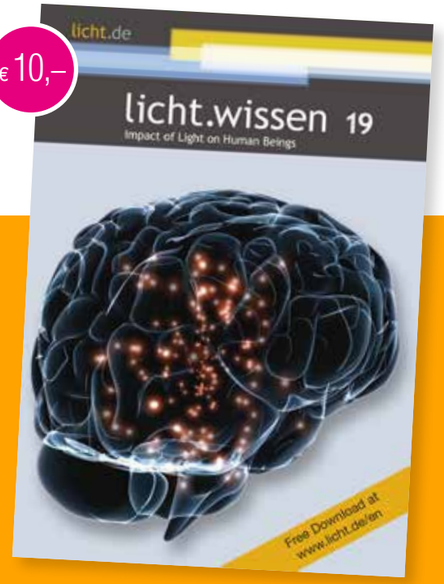

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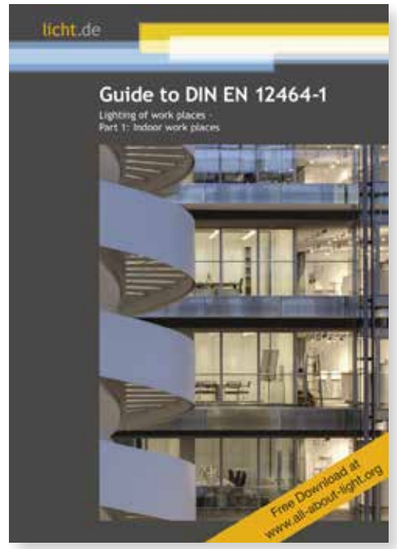

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