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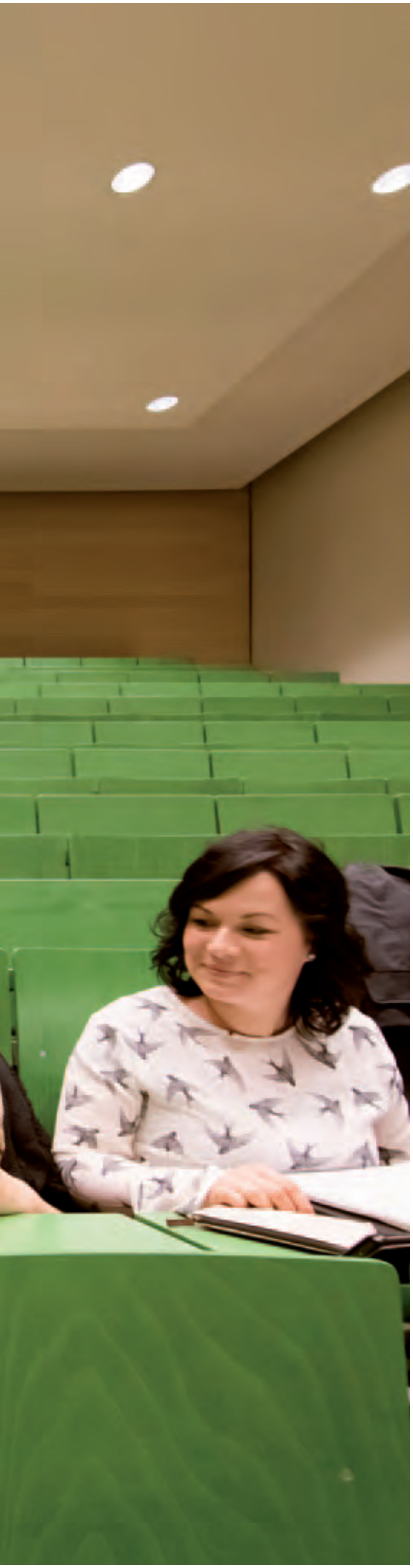
Learning in a New Light

01



Editorial

In recent years, teachers, head teachers and the public or private bodies behind the schools have had to assume more responsibility than ever before. They need to meet a whole range of curricular, methodological and educational criteria. However, the additional hours resulting from the shift towards all-day schooling and afternoon classes (in Germany, at least) have also added health aspects to their responsibilities. Child welfare organisations criticise our society for not encouraging greater movement in young children, for allowing them to become overweight and to develop coordination problems and myopia (short-sightedness), requiring them to wear glasses at an earlier age than would otherwise be required.

Smartphones, tablets and game consoles are often blamed for this, but the fact that pupils spend too much time in poorly or incorrectly lit rooms is often overlooked. It is not possible to influence how children spend their time outside school, however inside the school itself, ensuring good lighting is a key responsibility of the school authorities. Such aspects arise from the fact that education is a basic public service.

A further factor which can hinder educational performance is if teachers wait until it is almost dark before switching on the lights. Flickering lamps, a mishmash of light colours and dazzling spotlights should now hopefully be things of the past here in Germany. Nevertheless, there is still scope for meaningful and much-needed improvements.

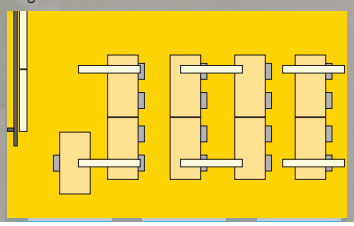
These include the blackboard/whiteboard area, which needs to be illuminated more brightly than the rest of the classroom. Mirroring the effect of sunlight, there should be a larger amount of blue light in the visible light spectrum in the morning, while in the early evening hours the lighting should have an increasingly warm colour. Different lighting scenes can be used to increase and decrease children's activity levels. Appropriate lighting can thus help students and teachers alike improve their educational performance.

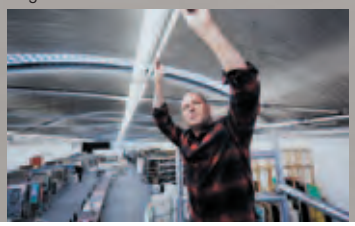
Refrigerator lights come on automatically whenever the door is opened – and the same principle could also be applied in classrooms, corridors and toilets. The lights come on if someone is there, but if the room is empty, they automatically go out. The rows of desks closest to the windows receive more daylight than those furthest away; artificial lighting is used to ensure that the entire classroom is evenly illuminated. And in schools with rows of adjacent classrooms all with the same lighting requirements, only one sensor is required per floor. The teachers would no longer have to worry about the lighting.

Anyone worried about the costs involved should first consider the proportion of lighting costs within the total operating costs of the building. If children need glasses at an early age and perform poorly because of bad lighting, this is to the detriment of society as a whole in the long run. Automatic sensor-controlled lighting coupled with user-oriented lighting designs benefit the teachers, students, parents – and even satisfy the accountants. This booklet contains plenty of helpful information on how to achieve this. It also highlights the benefits – and points out why the same considerations also apply to day-care centres. I have reduced costs by a third in my own offices by optimising the lighting design. And you can do the same.

Peter Baranec
Editor-in-Chief of Kommunalleasing Magazin KLM

Lighting standards





02

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Schools and lifelong learning

In the 16th and 17th centuries, the polymaths of the time were still able to explain the entire world. They knew everything there was to know. Today, that is simply impossible. Acquired knowledge and technological skills can be disproved or become obsolete in just a few years. We are in the "age of the knowledge explosion", as the Zukunftsinstitut (Future Institute) calls it, and are turning into a knowledge society – a society in which education is more important than ever.

Young people who complete a traineeship today can by no means be regarded as fully "trained" and can certainly not expect what they have already learnt to suffice for the rest of their lives. Instead, the rapid growth in knowledge requires everyone to engage in ongoing education and training. "Today's polymaths are therefore no longer people who know everything, but people with a clear idea of what they do and don't know," according to the Zukunftsinstitut.[1] Knowledge is losing its elitist character and is becoming common property. Indeed, the Zukunftsinstitut has identified knowledge culture as a megatrend that is set to change our society fundamentally in the long term. The enormous increase in knowledge, however, requires a new, reflective approach to information and the ways in which it is disseminated.

Today, education and training can therefore no longer be limited to what is learned in early life, rather they must become lifelong processes. And the sole aim of schooling can no longer be the accumulation of knowledge, rather it must also promote the development of skills that enable lifelong self-learning. It must produce individuals who have the techniques necessary for acquiring knowledge independently and who are flexible enough to adapt their learning to changing external conditions – as the recent pandemic showed us. At the same time, schools today have to deal with societal expectations surrounding all-day teaching and inclusion (see page 69). Furthermore, each individual educational institution is expected to have its own distinctive pedagogical profile.

So present-day schooling takes place under completely different conditions to those in the last century, when many of the buildings that are still in use today were built. Many schools of the time were designed with classrooms which branched off from long corridors that served primarily as circulation routes, and occasionally also as cloakrooms. In many places, traditional teacher-centred instruction is giving way to more modern teaching methods that take greater account of the learning needs of the individual pupils, and that make use of a variety of methods and learning locations.

Developing individuality

"Children and young people make best progress when they get to change their perspective frequently: becoming a listener, a speaker, an observer, a learner, a teacher," says Dr. Otto Seydel, head of the Institut für Schulentwicklung (Institute for School Development) in Überlingen.[3] In his view, conventional classrooms are basically not suitable for such learning. "If we confine the children to narrow benches like those of 100 years ago, then it is impossible for them to develop any self-learning skills. We need spaces where their individuality can unfold."

In many places, such needs are compromised by the considerable backlog in school building projects. Berlin, for example, launched a school construction offensive in 2017 which aimed to refurbish almost all schools by 2026 at a cost of more than 5.5 billion euros, and to build at least 60 new schools and extensions to create space for around 70,000 additional pupils. Hamburg and Munich have set up similar programmes.

"The room as the third educator"

New ideas for making use of space offer a great deal of potential for supporting the learning of the future. The concept of the "room as a third educator" is experiencing a renaissance. The idea was fashionable in early childhood education in the 1960s and

[02] Always on the move. Preschool children moving between the group painting table, the music corner and individual activity areas. (Photo: licht.de/Trilux)

[03] Effective double-act. Lighting solutions that integrate incident daylight create a sense of well-being and are energy-efficient. (Photo: licht.de/Ledvance)

[04] Modern pendant luminaires in the lecture theatre provide wide-area light which is practically shadow-free. They can also vary the light colour over the course of the day. (Photo: licht.de/Trilux)

1970s; it was then adapted by schools, only to vanish again.

"In the future we need to ensure that we invest not in outdated corridor-type school buildings, but instead in sustainable learning space typologies and high-performance educational facilities," writes the Montag Foundation, which was set up in cooperation with experts from the fields of education, architecture, urban development and planning, as well as representatives from the political and administration communities.[2]

Its approach is basically one of integrated planning in which the three areas of education, architecture and administration work together as a whole. It all starts in "phase zero", in which ideally all three areas collaborate on defining the utilisation requirements, the room programme and the spatial organisational structures before the first draft is created – or even before the invitations to tender are sent out. "Properly coordinated decisions in phase zero save considerable costs and resources in the planning and construction process as well as in later use," says the Foundation.[2]

Classroom-plus, clusters and learning landscapes

The purpose of all this is to create spatial environments that deploy educational architecture in ways which support the learning of the future. This architecture derives from three different types of learning space: Classroom-Plus – the conventional classroom is supplemented by additional areas that permit greater differentiation and create places of retreat or group spaces; Clusters and Compartments – multiple classes use a pool of rooms which can be combined and separated in various ways; Learning Landscapes – which dispense completely with classrooms and create learning situations in open spaces. Educational architecture can also be oriented towards the targeted or existing types of building, such as corridor-

type schools, atrium-type (see page 69) or pavilion-type schools. It also takes into account the chosen type of room allocation by which classes, year groups, subject areas or even teachers can be assigned to specific rooms. It also incorporates possible forms of individualisation whereby students are entitled to their own personalised or non-personalised work place.

The “Münchner Lernhaus” (Munich Learning House) was developed as a framework for contemporary spatial models and organisational forms. Based on clusters, it includes classrooms, group rooms and learning spaces arranged around a common central area. The purpose of this is to promote cooperation and flexibility when switching between the different forms of learning, and to open up spatial synergies. A school comprises a multitude of learning spaces – which can also be created by making minor structural changes to the existing building of a conventional corridor-type school. Hamburg and Berlin, by contrast, have developed timber-construction school modules based on the cluster principle: One or more units of the “Hamburg Class House” or the “Berlin Compartment” can complement existing schools or form a new school.[4]

Other cities, such as Cologne, are moving away from the classroom concept and instead are entrusting the decisions to the respective schools and planners – especially regarding the open learning landscape of the higher school years. Cologne is “departing from the conventional understanding of general learning and teaching areas divided into classrooms, and following the concept of more individualised and independent learning”, according to the definition of the “Pädagogisch-architektonischen Standards für die Stadt Köln”.[5]

The open school of the future

The learning and recreation areas and the staff rooms in the educational buildings of the future will merge into one another and offer plenty of space for flexibility and interaction. And sustainability will also require them to open themselves up as hybrid buildings for external use – its gymnasium for club sports and its schoolyard for the general public, for instance. All this requires careful planning and foresight – and not least the participation of experts who can help to devise a future-proof lighting solution. A solution that takes all the needs/functions of the school into appropriate account through suitable control systems, that supports lifelong learning, that ensures safety and that is also sustainable.

[05] E-learning and web seminars are important tools for lifelong learning in ongoing vocational training and development. Suitable lighting solutions make the workplace a pleasant learning environment. (Photo: licht.de/Trilux)

Helping children to see the light

Children and young people spend much of their time indoors – at school, doing homework or with their family and friends. Some environmental factors are difficult to influence – such as the basic form or location of an existing building or room. However, the lighting can be adapted to the specific needs of the users with relatively little effort.

Light has always exerted a powerful influence on humans – affecting our vision, our circadian rhythm, the quality of our sleep, our well-being and many metabolic processes in our body, such as vitamin D production. It also affects our capacity to perceive, pay attention and learn. The link between light and children's learning success has been proven in global studies and also in recent empirical studies devoted primarily to examining the effects of light intensity and natural light colour on learning.

Studies reveal how daylight improves performance

A review and a study of more than 2,000 school classes in three US states show how students who receive more daylight perform better in maths and reading tests than those in classrooms with less daylight.[7,8]

A study of more than 2,600 children in twelve European countries investigated how different lighting situations affect their performance at school. It revealed that south-facing classrooms and large windows in relation to the floor area have the greatest positive influence on children's learning.[9] A study conducted in India came to similar conclusions. Again, learning performance was significantly better when students received more daylight and their classrooms were better lit.[7,10]

Another study looked at the influence of the natural colour spectrum of light during the course of the day on learning and concentration, while a review examined the relationship between natural light colour over the day and reading performance in terms of accuracy, speed and expression.[11,12] The results showed that children who were taught in rooms with a natural colour spectrum had significantly better reading performance than pupils in the control group with poorer lighting. In addition, enriching the blue component of light yielded short-term increases in concentration levels and cognitive performance with regard to processing, speed and memory performance.[11] Prolonged exposure to blue light at the wrong time can lead to disruption of the circadian rhythm and, in the long term, to poorer sleep quality and reduced concentration.

Raising concentration and attention levels

Many internal and external factors influence attention levels and the ability to concentrate during learning – these include general health, emotions, nutrition, fatigue, but also motivation and interest in the subject matter. There are numerous factors which can distract and disturb children, such as an unpleasant room climate, noise, or movements within the field of vision.

Deliberate changes in room lighting – such as darkening the surroundings – can help redirect attention back to the lesson. Good illumination improves recognisability, for example when reading. Common consequences of unfavourable lighting include eye strain, distraction and neck complaints within a relatively short period of time. Daylight and good lighting are just two aspects here – but ones that can be readily influenced.

Poor sleep raises the risk of accidents

Numerous studies in recent years have concerned themselves with obtaining a better understanding of the positive factors relating to concentration and attention, and also with identifying negative influences. Some showed that increased accident rates, depression and metabolic diseases can be the result of too little sleep and poor sleep quality. The same applies to the use of mobile phones, tablets and LED screens in the evening. The blue compo-

nent in the LED colour spectrum seems to be particularly problematic, as are individual sleep habits.[13,14] Every year, overtiredness causes thousands of accidents at work and in traffic, and therefore represents a serious hazard.[15,16]

"Good lighting can have a positive impact on social behaviour"

Insufficient lighting or darkness can lead some people to feel inconspicuous and thus subject to less social control. This, in turn, can prompt them to break the rules. This is a phenomenon which has been observed in road traffic at night.[17] The reasons are the same: the less people feel observed, the lower the sense of social responsibility. Conversely, good lighting can have a positive impact on honesty and social behaviour.

The same study also revealed a greater willingness to help in good lighting conditions. Another study on risk perception and risk behaviour concluded that people generally have a heightened awareness of suspected risks in dark lighting situations.[18]

Get the day off to a better start after a good night's sleep

Natural light changes during the course of the day and the course of the year – with both also dependent on the latitude. The day in Germany is characterised by the colour spectrum changing from light reddish light in the morning to white-bluish light at midday and reddish-violet light in the evening. The light colour changes, but so, too, does the light intensity. Both aspects are important for the human day-night rhythm, or the circadian rhythm as it is more accurately termed (see page 68). People whose inner clock is functioning properly and who have had a restful night's sleep start the day well.

Why is light colour also referred to as colour temperature? The term stems from a particular phenomenon: the different

[06] Teaching methods, teaching materials and everyday life at school have changed greatly in recent decades – as have the demands on lighting. (Photo: licht.de/Trilux)

Sven Hoffmann
Programme Manager for Work+Health at the University of Zurich and Lausanne

colours which metals take on as they are heated in the forge – first becoming red-hot, then white and finally bluish. Today, the colour temperature of light is defined in relation to a "black body" that is slowly heated. It is expressed in kelvins (K). Colour temperatures below 3,300 K are referred to as warm white, 3,300 to 5,300 K as neutral white and those of more than 5,300 K as daylight white, also commonly known as cool (or cold) white.

Cool, planar light with high illuminance levels boosts activity, while low, reddish colour temperatures of lower brightness tend to have a calming effect. The sky provides such a dynamic range and quantity of light and colour. Depending on the time of year, daylight in a cloudless sky has a colour temperature of roughly 3,000 K in the morning, 5,300 to 5,800 K at noon and less than 2,000 K in the violet evening sky. Sunlight illuminance levels reach about 100,000 lux, while only roughly 0.2 lux is measured on a moonlit night. An overcast sky on a winter day can still deliver around 3,500 lux. 500 lux is common in classrooms – this is enough to see, but does very little to satisfy our body's requirement for light.

Today we can do a lot to help learners and teachers by providing the right amount of the right kind of light at the right time. The better the light is adapted to the learning situation, the more information can be absorbed, processed and stored. Good illumination with cool white light raises attention and concentration levels. Warm light colours and subdued lighting tend to favour calmer group discussions and reduced tension levels after tests.

"There is a strong link between the use of electronic devices and the evening chronotype, up to and including sleep problems"

Similar to adults, children also have different day-night rhythm preferences (see page 68 for chronotypes).[19] A recent study shows a close connection between the regular use of electronic devices and the evening chronotype.[20] In addition to causing major sleep problems in some cases, the children examined in this study who had an evening chronotype "forced" upon them also showed a greater tendency to depression. This group benefits in particular from optimally lit classrooms. However, long-term synchronisation is an even better solution. The internal clock of older children and young adults runs at a different rate to the education system; they are 'late' types. Many students are still in sleep mode in the morning but wide awake late in the evening. They have different lighting needs to adults, who are often taught in the evening. Good lighting design takes all these factors into account and creates the

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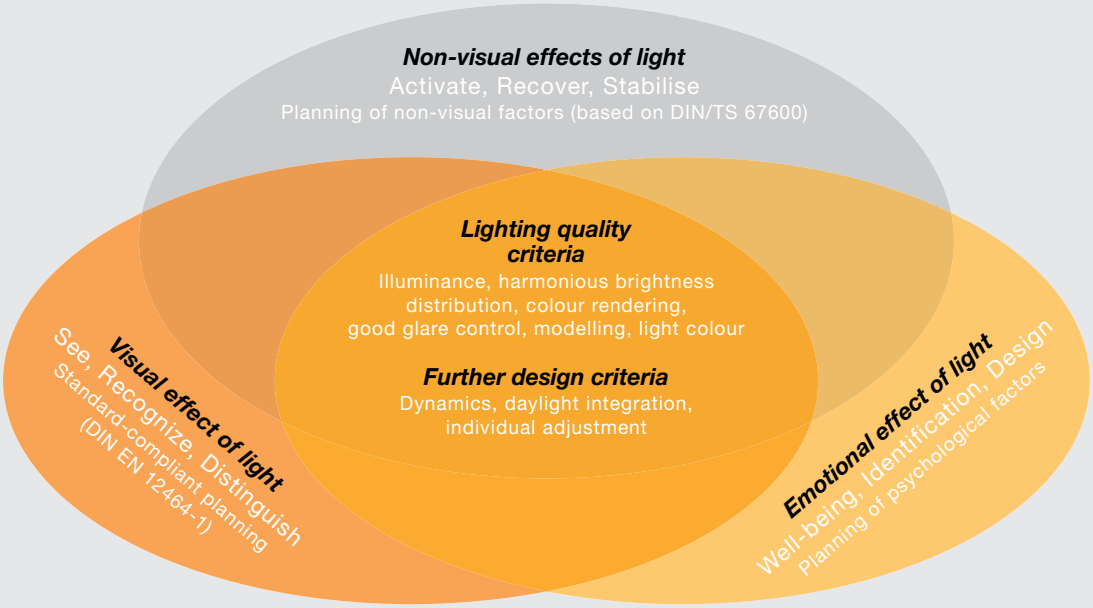
Human Centric Lighting (HCL)



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The criteria of lighting quality are closely linked to the non-visual, visual and emotional effects of light: daylight utilisation, colour temperature, dynamics, colour rendering, glare limitation, illuminance, light distribution and modelling. All these factors must be incorporated in a Human Centric Lighting (HCL) design (see page 69).

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best possible learning environment as the basis for academic success and the well-being of children and young people.

You can read about the effect which light has on the human body in licht.wissen 19 “Impact of Light on Human Beings”. licht.wissen 21 “Guide to Human Centric Lighting (HCL)” provides design guidance.

[07-09] Changing the lighting in a room can stimulate learning processes. The right composition of light at the right time supports the body’s natural processes during the course of the day. Human Centric Lighting (HCL) provides ideas for raising activity levels and aiding recuperation. (Photos: licht.de/Zumtobel, photographer Jesper Malmkvist)

09

11

Learning easier with digital support

In the nursery, at school or at home – learning should be enjoyable. That is why various learning theories and educational concepts concern themselves with the best ways to support the acquisition of knowledge and the memorisation of information – both in the real world and the digital space.

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Numerous digital tools – including learning platforms, and virtual classrooms and meeting rooms – are now available to support teaching in educational institutions and children's bedrooms. A broad range of offerings is available, since each federal state has its own specifications on data protection and quality standards for digital learning materials.

Tablets, projectors and smart whiteboards are as much a part of today's classrooms as blackboards and chalk were in the past, which they have already replaced in some cases.

One of many modern options for providing secure internet access for students' devices is Li-Fi (see page 69).

[11] Computers and tablets are now part of everyday school life. (Photo: licht.de/Signify)

[12] Compact tablets do away with the need to carry heavy books, and make school bags much lighter. (Photo: licht.de/Signify)


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Effective learning at home

To ensure that learning at home is fun and effective, school students need a set place where they can do their homework. Pandemic-induced home-schooling could also return to children's and young people's bedrooms at any time. A well-equipped and adequately lit desk is therefore indispensable.

[13] Reading texts, interpreting charts, writing by hand – these are demanding visual tasks which require sufficient brightness. (Photo: licht.de/Signify)

Uniformly distributed light in children's and young people's bedrooms promotes concentration because the eyes do not have to constantly adjust to different brightness levels (adaptation). licht.de recommends a properly positioned desk luminaire to supplement the general lighting (see chart on page 63) and a bedside lamp for reading in bed.

At the centre of it all – the desk

The main focus should be on the desk light-ing. Homework is made easier with a rotatable and swivelling desk luminaire or an anti-glare pendant luminaire suspended above with direct and indirect light components. Wall-mounted or floor-standing luminaires are ideal for casting indirect light on the ceiling and walls. Ceiling luminaires which emit diffuse light, or track systems with wide-beam luminaires, are also suitable. Important elements in living space design are high-quality luminaires which emit a good quality of light.

Staring for long periods at a screen is tiring

Staring constantly at a computer screen puts a strain on our eyes, as it is an activity they are not designed for. This is because we blink less during longer periods of concentrated DSE (digital screen equipment) work. The consequences are dry, tired and painful eyes.

Home-schooling can exacerbate these problems because the display is usually small and the lighting inadequate. Breaks from the screen, regular ventilation and better light can all help. Students should also let their gaze occasionally wander – which is good for their eyes and overall well-being. In contrast to adults, excessive screen time can actually lead to myopia in children. To compensate, they should spend enough time outdoors in daylight.

Turn on the camera and look good

When schoolchildren and young people turn on the camera in their online lessons, they naturally want to look their best. But the image quality and lighting are not always optimal for this. Anyone wishing to show themselves in the best possible light, should make sure that their face is evenly illuminated by properly angled light sources:

- The best light for online teaching is from the front and slightly above. This helps to avoid unflattering stark shadows.
- Large-area luminaires create soft shadows and provide pleasant levels of vertical illuminance.
- Glare can be avoided by shielding.
- The background should not be too bright – otherwise the subject will appear in silhouette and the face too dark. It is therefore better for participants not to sit with their backs to a window. The background of the picture should be as unobtrusive and uncluttered as possible.

Light lifts the mood

Variety is the spice of life. Spotlights directed at an attractive object in a room, or a chain of lights can create a pleasant atmosphere with varied contrasts. However, any accent lighting luminaires should be positioned to ensure there are no reflections on the screen where they can cause glare.

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[14] Students need a desk with an ergonomic design and good light where they can do their homework or work on a PC. (Photo: Pixabay/Artistic Operations)

[15] Everything looks better in the right light – even in virtual lessons. (Photo: iStock/FG Trade)

Illuminance in lux

Work area lighting should be at least 500 lux, with 300 lux sufficient for the surrounding area.
Brighter light is desirable for some jobs. Such flexibility can be provided by dimmable luminaires.

Anyone wishing to obtain a precise reading of the illuminance in lux can use a measuring device (illuminance or lux meter) at several points on the work surface. Apps provide approximate values.

CHECKLIST
Check yourself

Home-schooling

• Lighting • Products • Tips

licht.de

Desk lighting*

- ☐ Desk sufficiently bright – surroundings not too dark
- ☐ Desk position: perpendicular to the window
- ☐ Video mode: being seen in the right light
  - uniform illumination, preferably including ceiling illumination
  - avoid stark shadows: no directional spotlights directly above the head
  - no window directly behind
- ☐ Sun protection against glare and reflection
- ☐ View of outdoors: allow gaze to wander for a while
- ☐ Only warm white light in the evening, at least 2 hours before bedtime

Buying tips

- ☐ High quality, long-lasting products
- ☐ Save electricity with a daylight control system and presence sensors
- ☐ User-friendly operation (switch, dimmer, touch, app, speech)
- ☐ Ceiling light: shielded, dimmable **
- ☐ Pendant luminaire: shielded, dimmable, with indirect light component**
- ☐ Floor-standing luminaire next to desk: shielded, dimmable, with indirect light component**
- ☐ Supplementary desk lamp: individually adjustable
- ☐ Spotlight or wallwasher for illuminating walls: adjustable

Recommendations for lighting settings

- ☐ **Illuminance:** at least 500 lx on work surface – preferably more

  How to check:
  - precise measurement using light meter (lux meter), or approximate measurement using app
  - at multiple points on the desk
- ☐ Uniform **illumination** of the work surface
- ☐ Pleasantly bright ceiling and walls
- ☐ Light direction:
  - avoid annoying shadows
  - light from desk and floor lamps: for right-handers from the left – for left-handers from the right
- ☐ Avoid **glare** and reflections by:
  - carefully positioning the luminaires
  - using well-shielded or covered light sources
- ☐ **Light colours:**

Home lighting:	warm white (WW = 2,700 – 3,300 K)
Promotes concentration during the day:	daylight whit (DW = > 5,300 K) tunable White (2,700 – 6,500 K)

- ☐ Good **colour rendering** (≥ R_a 80)
- ☐ Light switches off when no-one present: manually or via sensor

* The work is conducted on the screen and at the desk
** If sole work area luminaire: luminous flux > 6,000 lm

Day-care centres – Light for little discoverers

Balanced lighting in day-care centres allows young children to explore and investigate the world safely in a protected environment. Light that is adapted to the needs of children and staff promotes visual receptiveness and contributes to a sense of well-being.

[17] Mobile luminaires are risky: a child's imagination can soon turn a floor lamp into a light sabre. (Photo: licht.de/Signify)

[18] Appropriate lighting for day-care centres and nursery schools ensures safety, creates an-atmosphere of well-being and allows the children to enjoy calmer moments. (Photo: licht.de/Zumtobel, photographer Isabelle Bacher)

Young children are curious, have countless questions, are keen to discover and try things out. They learn through observation and imitation. Children need to be able to move, play and let off steam – but they also need to be able to relax and slow down from time to time. Child day-care centres must enable them to do all these. They are an important part of the educational system, supporting and promoting the overall development of young children and the social contacts with their peers.

Open and closed concepts

Similar to other educational institutions, there are many different types of day-care centre – including everything from municipal and private providers to parents' initiatives.

Two basic forms are the open and the closed concept. Their different approaches influence the design of the lighting solutions because they have different requirements in terms of room layout and design.

A room for all purposes

In the closed concept, each group has its designated room where the children spend most of their time. It is multifunctional and should have different areas for the different purposes. These include tables for painting and eating, a quiet corner for reading, a place for building, the "home corner" with a play kitchen as well as a dressing-up and doll's corner. This is often used for a midday nap.

Sufficiently bright basic lighting, with good colour rendering, that can be dimmed in different zones is essential. In the quiet corner, separate lighting with warm light colours – which is also suitable for story-telling – is important. "Stage lighting" for the dressing-up and dolls' corner turns junior amateur actors into big stars.

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Playroom safety

Children want to be able to play, run around and move freely [16]. The furniture and lighting should enable this. The furniture should have no sharp edges, and the luminaires should have a closed design which prevents children from injuring themselves. Childproof installation is also important. Ball-proof luminaires can be practical in multi-purpose rooms. It is inadvisable to use mobile luminaires due to the high risk of injury.

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Open house
The open concept allows the children to move freely throughout the building. Each room has its own theme and the children choose where they want to be. The lighting is matched to the function of the room.

The “building block”, creative and dining areas need bright and uniform illumination of the room surfaces with neutral light colours and good colour rendering to ensure good visibility.

The “snoozle” room as well as the sleeping area require a relaxed, calming atmosphere created with warm light colours, different light sources and light distributions, and should be suitable for reading. Lighting zones that can be controlled and dimmed independently of each another are advantageous.

Ball-proof luminaires are the right choice in sports and exercise rooms. Uniform and glare-free light in a neutral white colour is best here.

Corridors, cloakrooms, washrooms, kitchens and staff rooms should be planned in line with the appropriate standards (see page 63). Uniform illumination of these areas creates good visual conditions and also promotes cleanliness and hygiene. Different types of accent lighting can be used to enhance corridors and cloakrooms, which often also serve as galleries for the children’s artwork.

Keep luminaires out of children’s reach
The different rooms in a day-care centre should have their own lighting design and lighting system. Safe options include enclosed luminaires with no sharp edges that are mounted out of the children’s reach. Floor, table or wall lamps with their own electrical connections are not suitable. Pendant luminaires which distribute the light both directly and indirectly create a pleasant atmosphere and have the optical effect of enlarging the room.

Electric lighting is indispensable in the morning hours, especially in the dark season from September to April. Plenty of incident daylight is good, but there should be no glare. Automatically controlled sunshades can help – and serve to reduce heat gain in summer.

Today’s knowledge of the interrelationships between the visual, non-visual and emotional effects of light on people also opens up a wide range of design options for the lighting of day-care centres. Appropriate lighting can stabilise circadian rhythms on a long-term basis, bright light and high colour temperatures can have a powerful positive impact on concentration levels, whereas low illuminance levels and warm white light colours have a calming effect. The planning should also include the colour design of the room surfaces and furniture, as they, too, influence the effect of the light.

Potential ways to exploit the effects of light are described in licht.wissen booklets 19 and 21. DIN/TS 67600 contains “Complementary criteria for lighting design and lighting application with regard to non-visual effects of light”.

[19] Initially, children often find it difficult to be separated from their parents in the day-care centre. Appropriate furnishings and lighting can do a lot to make small children feel instantly at home in their new surroundings. (Photo: licht.de/Erco, photographer Dirk Vogel)

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Classrooms, blackboards and whiteboards

Primary schools bring together children who have completely different sets of knowledge and learning requirements. The lessons need to take these individual circumstances into account so that the pupils can improve and expand their knowledge and skills. Much of the learning takes place through the visual medium. Good lighting is a prerequisite for concentrated working with low visual fatigue, and makes a decisive contribution to increasing the attentiveness of schoolchildren.

Rigid seating arrangements and teacher-centred instruction in the classroom are largely things of the past. They have been replaced by new forms of communication. The purpose of flexible solutions is to use the room design to support the achievement of learning objectives. The lighting must also be able to adapt to different learning and teaching situations – including group work and project presentations – and be easy to operate.

Avoid glare

Natural daylight is the first choice when it comes to achieving uniform illumination of the classroom. Dimmable lighting can be supplemented as required. However, glare is an unpleasant disruptive factor. It impairs vision and students' ability to concentrate in class. As long as all important information remains recognisable, most people have a greater tolerance of daylight glare than glare caused by artificial lighting. However, sun shading can protect against this and also regulate the heat gain. Glare from artificial lighting can be avoided with the right choice and arrangement of luminaires.

Variable lighting for flexible room use

Rooms can be used flexibly given the right selection and arrangement of luminaires. The precondition for making flexible use of the room is uniformly good lighting throughout, even if the tables and chairs are rearranged. This is why licht.de recommends lighting solutions which take the entire room into consideration. The walls, including the rear wall, must be well lit. The classroom should be evenly illuminated to avoid major discrepancies in luminance distribution from different viewing angles. This is because excessive deviations reduce attention and cause the eyes to tire quickly. Compliance with the specified R_{UG} limit values for glare must be verified using the UGR table method.

For flexible or floor plan-orientated classroom seating arrangements, the luminaires need to be positioned in a directionally neutral way. Furthermore, they must not cause glare from any direction. Additional lighting for presentation surfaces depends on the type of system used – and is still necessary in many cases.

Daylight-orientated light incidence for fixed seating arrangements

Continuous-row lighting systems – recessed, surface-mounted or suspended – are usually used for conventional seating arrangements in which the main direction of view is towards the board. The number of rows depends on the depth of the room. The minimum is two rows of luminaires: one close to, and one away from, the window (2/3 room depth). They are usually installed parallel to the direction of view and the window façade. This arrangement creates a daylight-orientated incidence of light with soft, unobtrusive shadows.

Ensuring visual comfort with light management

LED luminaires combined with light management systems provide an effective lighting solution. They supplement the daylight and ensure that an illuminance of at least 500 lux is always available in classrooms and teaching spaces, as specified in DIN EN 12464-1. This standard value is regarded as the required maintained value, however a higher illuminance of 750 lux is particularly advantageous in the early morning and in the evening, and during the winter months. There is generally a good amount of daylight in primary schools, and the illuminance can be dimmed to 300 lux. Lighting control systems make it easy to

[20] Evenly lit classrooms avoid excessive contrast and help prevent eye strain. (Photo: licht.de/Signify)

[21] Schools are products of their time and reflect the contemporary trends. They must fulfil all relevant structural and equipment requirements. (Photo: licht.de/XAL, René Riller Photography)

select different lighting scenarios – such as lectures or examinations – via touch panels, multifunction switches or tablets. Intelligent, networked control systems automatically detect the level of natural light currently available and the amount of brightness needed by users in the room at any given time. If a monitor or a projector is switched on during the day, the light is automatically dimmed and adapted to the new situation. Such automatic functions can be highly practical, yet it should always be possible to manually override the automatic control system. Simple and intuitive setting options are called for here.

Controllable luminaires and light management systems are also indispensable if Human Centric Lighting (HCL) is to provide positive support for the well-being, motivation and concentration of learners in schools (see page 69). Presence detectors save energy and costs by switching off the lighting in the room at the end of the lesson.

Blackboards, whiteboards and monitors

The wide range of new presentation media require equally differentiated lighting solutions. It is important that the lighting of vertical boards and presentation surfaces is uniform and sufficiently bright. Otherwise the constant changes in lighting level can be tiring on the eyes as the gaze shifts.

Blackboards, greenboards or whiteboards and large monitors are now standard equipment in classrooms. The content shown on these vertical presentation surfaces must be easily recognisable from all points in the room. The visual task is the same for all these surfaces – however they each have different lighting requirements. As little light as possible should shine upon the surface of the monitor; traditional blackboards and whiteboards require sufficiently bright and uniform lighting; however, the very bright surfaces of whiteboards are susceptible to reflection and glare.

[22] Three ceiling-mounted rows of lights arranged parallel to the window façade provide homogeneous and glare-free light. (Photo: licht.de/Trilux)

Uniformity for non-self-luminous presentation surfaces

Luminaires which emit light asymmetrically (such as wallwashers) are the best choice for bright and uniform illumination of non-self-luminous presentation surfaces. These supplement the general lighting. Also suitable here are recessed, surface-mounted or pendant luminaires as well as wide-beam, track-mounted spotlights. These run parallel to the white or blackboard and cover its full width. The correct distance to the board is between 0.85 and 1.30 metres. The vertical light gives an impression of greater brightness and increases the sense of distance.

DIN EN 12464-1 recommends an average vertical illuminance of 500 to 750 lux for presentation surfaces. The uniformity U_o – the ratio of the minimum to the average illuminance – should be at least 0.70, the colour rendering index at least R_a 80. Boards that can be unfolded and moved up and down, flipcharts and wall maps should be illuminated over their entire surface.

Pre-set lighting scenes

For media presentations displayed using a monitor or projector, it should be possible to dim the lighting or switch it off separately – including the lighting for side panels and wall displays. Lighting control systems that can instantly call up various pre-set lighting scenes with the help of user-friendly control panels offer maximum convenience. Nowadays, this is often also possible using an app on a tablet or smartphone. Modern password protection provides security.

Whiteboards are more susceptible to reflection. Any light sources nearby should therefore be well shielded. Reflection and glare can be avoided by the right choice and arrangement of luminaires.

LiTG Publication No. 30 provides guidelines for the planning and operation of lighting systems in private classrooms, lecture theatres and conference rooms.[6]

[23] Vertical black- or whiteboards and media presentation surfaces need uniform and sufficiently bright lighting to avoid eye strain in students due to constantly changing lighting conditions as their gaze shifts. (Photo: licht.de/Trilux)

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Black/whiteboard lighting

The following points should be observed for good illumination of the white or blackboard [24]:

- Illuminance of at least 500 to 750 lux on the vertical surface
- Reflected glare, e.g. from narrow-beam spotlights, should be avoided.
- The colour rendering index must be at least R_a 80.
- The uniformity of the board lighting must be 0.70 (ratio of minimum to average illuminance).
- Flipcharts or wall maps hung next to the black or white board should also be evenly illuminated by wallwashers.

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Specialist subject rooms

The range of subjects broadens for students as they progress through school – further options such as computer science and chemistry are added. Specialist subject rooms have their own individual requirements in terms of materials, equipment and lighting.

Experiments are an integral part of science lessons, for instance. Many experiments – such as demonstrations of hydrogen deflagration or refractive prisms – leave a more lasting impression than any description can. To ensure the same effect even with smaller objects, a sufficient lighting level is important in specialist subject rooms: at least 500 lux. The more exacting the visual task requirement, the greater the illuminance needs to be.

It should be possible to dim lights in specialist subject rooms, especially at the front of the classroom when monitors or projectors are used, or a compelling experiment is being conducted on the teacher's desk. Light management systems can pre-program customised lighting scenes which can then be called up quickly and simply as required (see page 44).

Avoid distractions
Glare-free vision is important in all specialist rooms, regardless of the subject. The direct glare value is determined using the unified glare rating method (R_{UGL}) and should be at least 19 (see page 60-61). Unwanted strobe effects should be avoided in all circumstances. This is mandatory in LEDs and modern light management systems.

Safety is the top priority in laboratories
To ensure the safe handling of chemicals and technical equipment, there should be no shadows or reflections in the work area – on glass or metal, for example. Luminaires with significant indirect light components increase vertical illuminance, making for bright rooms with harmonious light distribution and soft shadows.

Experiments and demonstrations involving fire or highly flammable materials are conducted in specially designed areas. For these areas and for the teacher's bench, licht.de recommends explosion-proof luminaires with IP 66 protection.

It must be possible to exit the laboratory safely in an emergency. Steps must therefore be fitted with stair lights, and exits equipped with safety lighting above the door (see page 50). If required, additional technical facilities can be attached to a suspended continuous-row system; these range from safety signs and motion detectors (or other sensors) to loudspeakers.

The problem of dust in workshops
Dust and airborne particles are stirred up in art and craft rooms where students work on wood, fabrics, stone or metal. Ignition- and flame-proof luminaires must be fitted in woodworking workshops and similar areas where high levels of dust are generated.

Accurate discernment of colours
Chemicals and printed matter are often distinguished by slight colour nuances. The smallest discolourations in Petri dishes and colour markings on cables and terminals must be clearly discernible. It is therefore crucial to have good – or preferably very good – colour rendering ($R_a \geq 90$). High-quality protective glass panes covering the luminaires should retain their colour neutrality over many years.

Painting and drawing
Being able to discern different colours correctly plays a particularly important role in art lessons. Demanding visual tasks such as drawing, where precision and accuracy are essential, require a higher level of illumination. DIN EN 12464-1 specifies at least 750 lux in art rooms. This can be increased to 1,000 lux for even better visual performance.

[25] Specialist subject rooms must be illuminated to at least 500 lux. (Photo: Adobe Stock, Koto)

[26] Avoiding glare is the top priority when working at a screen. (Photo: licht.de/Zumtobel, photographer Ancinec Lubomir)

Shadow-free music rooms
In music rooms, it is important to be able to play the instruments with great precision and to read the music with ease. Luminaires with an indirect light component help to avoid disruptive shadows and glare. The lighting needs to be uniformly good because bands, choirs and orchestras all occupy different positions in the room.

Media rooms – DSE-based work
Work at a computer screen is part of everyday school life. Ensuring a good balance between the brightness of the screen itself and the work area and its surroundings supports students working on a PC, laptop or tablet (see page 42).

Strong daylight and direct sunlight can make DSE-based (Display Screen Equipment) work difficult. Reflections from bright windows on the screen can be avoided by using appropriate sun protection, which can be linked for convenience to a lighting control system.

Ergonomically designed lighting that can be adapted to a particular activity, teaching style or mood prevents the eye-strain and discomfort often associated with DSE-based work. Even in rooms that often need to be darkened, light management based on Human Centric Lighting (HCL) can compensate to some extent for the lack of natural daylight while having a positive effect on students' well-being and their ability to concentrate (see page 69).

The non-visual effect of light, the basic principles involved and the best ways to exploit it, are described in licht.wissen booklets 19 and 21.


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[27] Musicians often sit or stand in different positions depending on the instrumentation and type of rehearsal. Consistent lighting quality must be available in all areas. (Photo: Adobe Stock, MonkeyBusiness)

[28] Art and craft rooms can generate highly flammable dust. Accordingly, luminaires with a correspondingly low surface temperature should be installed for such use. (Photo: licht.de/XAL, Z. Gataric Fotografie)

[29] Pupils need to watch closely during experiments. Pre-programmed lighting scenes ensure the right light for such situations at the touch of a button. (Photo: licht.de/Ridi)

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Energy efficiency and modernisation

It is important that educational establishments, too, now make economical use of increasingly scarce resources and energy-efficient lighting technology as a matter of course; this includes the intelligent use of lighting management. State subsidies are available for the modernisation of outdated lighting systems.

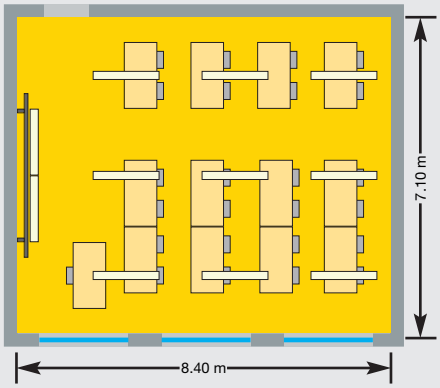
[30] Arrangement of luminaires with variable colour temperature, delivering a maximum illuminance of 750 lux (lx), based on the recommendation in DIN EN 12464-1: Light management system for circadian control of the colour temperature, occupancy detection and daylight-dependent control with a permanent target of 500 lx, including additional manual dimming function and activation of pre-set lighting scenes. (Graphic: licht.de)

The Building Energy Act (GEG) in Germany sets out requirements for the primary energy demand of new buildings; for existing buildings, they only apply to extensive refurbishments that require planning permission. All public buildings must have an energy performance certificate that shows the energy consumption or energy demand of the building. The certificate must be made publicly available. Revision of the European Energy Performance of Buildings Directive (EPBD) is currently pending (2023). It will seek to tighten the requirements for the worst performing buildings (WPBs). The phasing out of many conventional lamp types is also focusing attention on energy-efficient lighting. Its most important components are modern luminaires containing LED light sources, as well as occupancy detection and daylight utilisation controlled by a light management system (see page 44).

Outdated lighting systems in schools do not meet today's lighting quality requirements and cost a lot of money to maintain. The European lighting standard DIN EN 12464-1 now stipulates an illuminance of at least 500 lux for classrooms – up from the previous figure of just 300 lux. Soiling and material ageing mean that the systems in many cases no longer provide the lighting levels they had at the time of installation. In order to bring the lighting quality up to today's standards, modernisation is the appropriate solution in most cases and should always be considered for existing buildings. The low energy requirements of LED luminaires which are used in combination with a light management system allow the purchase costs to be recouped in just a few years. Modern systems also reduce maintenance costs.

Space-saving LED technology, which is more powerful and energy-efficient, can also be used in listed buildings without having to alter the architecture. Representing a discreet solution, the latest lighting technology can even, under certain circumstances, be integrated into existing luminaires.

Example of classroom modernisation



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Energy saving 85%

	Old system	New system
	T8-luminaire 2 x 58 W opal diffuser	Suspended luminaire with microprismatics and variable colour temperature for general and board lighting
No. of luminaires	6	9 + 2
System output per luminaire	132 W	44 W/37 W
Max. illuminance	–	750 lx
Effective operating hours/year	1.400	482*/560**
Energy/year	1.109 kWh	169 kWh
Energy saving		**85 %**

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* The effective operating hours are based on constant daylight-dependent control of the lighting to a target value of 500 lx and on the light being switched off when sufficient daylight is available or when no-one is present.
** The effective operating times of the black/whiteboard lighting are based on the light being switched on and off manually as required, and automatically switched off when no-one is present.

Measures and criteria for improving lighting quality and energy efficiency

Rooms
- Maximum utilisation of daylight
- Light walls, ceilings and floors

Luminaires
- High luminous efficacy
- Effective light distribution thanks to optimised optics for each particular application
- Dimmability with standardised interface

Lighting management
- Daylight and occupancy monitoring
- User-friendly operation, and pre-set lighting scenes
- Intelligent control strategies including sun screening

Lighting concept
- Activity-based instead of room-based design
- Use of switching groups for differentiated illumination and lighting effects
- Dynamic adjustment of light based on Human Centric Lighting principles

Systematic modernisation
A structured modernisation process helps to identify user expectations and potential efficiency increases at the general level, and ensures high lighting quality and low electricity costs over the long term. The underlying modernisation plan first compares and balances the cost-effectiveness of various measures and options. This helps determine the optimum modernisation strategy. The modernisation can also extend over several years and be carried out in stages. In this case, it will begin in the rooms or parts of the building where the lights have been in operation the longest. Alternatively, the luminaires and light sources offering the greatest savings potential can be installed from the outset in all rooms.

Step 1: As-is analysis
Every modernization project begins with an as-is analysis. Important information includes:
- Power bills from the last three years
- List of the maintenance and repair costs of existing systems
- Photometric analysis and inspection of the system. Digital surveying technologies now allow the entire building, including all technical equipment, to be charted and the results to be used as the basis for subsequent planning calculations, up to and including the BIM-based planning method (see page 68).
- Interviews on the experiences and expectations of users

Step 2: Planning
Key aspects of lighting planning: visual tasks must be defined, standards and directives need to be observed and lighting quality characteristics should be taken into account.

Planning also includes conducting a profitability analysis. It considers various options and compares different lighting solutions. It also lists the total costs of the lighting system over its entire life cycle. Relevant variables are
- Investment costs
- Energy consumption
- Costs for cleaning, maintenance and repair
- Disposal costs

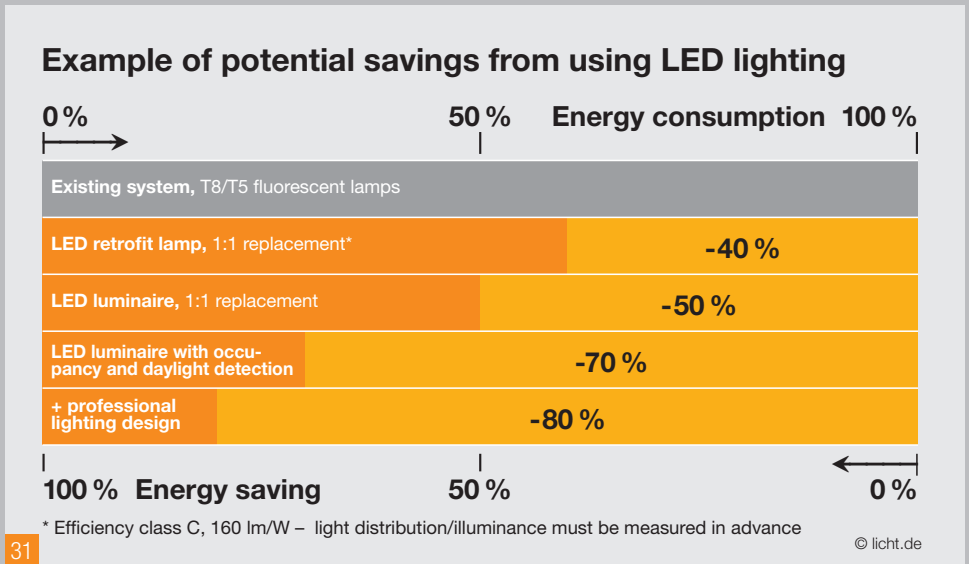
Step 3: Financing
Attractive financing models make it easier to switch to energy-efficient lighting. These include contracting, hire purchase, leasing and financial subsidies. The government and the federal Kreditanstalt für Wiederaufbau (www.kfw.de) have numerous support programmes for the modernisation of old lighting systems. The database of the Federal Ministry of Economics and Technology provides an overview of federal, state and EU subsidies and loans: www.foerderdatenbank.de.

Step 4: Cost-effective procurement
Contracting authorities are bound by public procurement laws and regulations regarding the purchase of goods and services. The regulations provide pointers on important criteria such as life cycle, cost-effectiveness and return on investment aspects, and govern the decision-making process. Under public procurement law, the best price in not the deciding criterion, rather the most cost-effective offer.

Step 5: Maintenance and inspection
Lighting design also includes drawing up a maintenance plan in accordance with DIN EN 12464-1. This is because optimum maintenance increases the service life and efficiency of lighting systems (see also Degradation on page 68). Valuable information and key performance indicators can be obtained for future projects if maintenance work is properly documented and analysed.

Light as a service
Many manufacturers and service providers also offer lighting-related services. “Light as a service” can take different forms up to and including complete packages which comply with public procurement law. These include the design, planning, manufacture and delivery of the system components, their installation, commissioning, operation and maintenance as well as subsequent recycling or disposal.

[31] Switching to energy-efficient LED luminaires in combination with a light management system and a professional lighting design saves electricity and operating costs. (Graphic: licht.de)



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Professional lighting with LED light sources

There are particularly exacting requirements for light sources in the education sector. They should deliver good light quality, be robust, flexible to use yet visually appealing – and have the lowest possible investment and operating costs. There are three possible options for modernisation, depending on the condition of the existing system: lamp replacement (retrofit), conversion or new installation. A large number of traditional lighting technologies are gradually disappearing from the market. Many are therefore seizing the opportunity to replace the old lighting with new, energy-efficient and convenient LED luminaires.

LED retrofit lamps

Even replacing a simple lamp can save a lot of energy. This makes sense as a temporary solution if, for example, the lighting system is not yet completely outdated and can be retained. Incandescent lamps can easily be replaced by LED lamps [10, 9]. The range of LED retrofit lamps as replacements for compact fluorescent lamps [7, 6] and ring lamps [5] is growing all the time. High-intensity discharge lamps can usually only be directly replaced by low-wattage LEDs [8] up to a maximum of 400 watts.

There is an extensive portfolio of LED tubes [1-4], and it is not always easy for users to find the “right” retrofit. Which ballast units are compatible and how high the luminous flux should be must be clarified in advance. Manufacturers and retailers provide help in the form of online tools and advice.

As a rule, the replacement of a lamp also changes the light distribution. It is therefore advisable to entrust the planning of such lamp replacements to professionals who

can then assess whether the required (possibly higher) illuminance levels are achieved. In doing so, they will take the maintenance factor into account and ensure that glare is avoided.

Energy savings and payback periods depend on the type of lamp in question and must therefore be calculated individually for each lighting system.

The service life of the newly installed lamps is generally longer, thereby extending their maintenance cycle, which must also be taken into account in the maintenance schedule.

Conversion
Conversion to other light sources must be carried out by a specialised company. Luminaire conversion is appropriate if, for example, existing luminaires will continue to be used (listed buildings/fire protection). The same applies if the user of the building wishes to go further and install a lighting control system or optimise the lighting technology, for instance.

Once the luminaires have been converted, all values must meet the requirements and be rechecked.

New installation
New lighting installations, on the other hand, offer more design options and enhanced learning environment functionalities. They can also be customised to meet the specific needs of students and teachers. They are more energy efficient and reduce operating costs. New lighting systems quickly pay for themselves as investments in the future, especially if lighting management is integrated into the building management system.

[32] 1) T8 LED light source as a replacement for fluorescent lamps
2) T5 LED replacement
3,4) T8 LED retrofit
5) T9 LED replacement for ring-shaped fluorescent lamps
6) Retrofit for compact fluorescent lamps
7) LED replacement for compact fluorescent lamps
8) LED retrofit for mercury vapour lamps
9) LED replacement for general-purpose light bulbs
10) LED light source E27

[33] Example of modernisation: Many conventional lamps can no longer be sold on the market because they consume too much energy or contain hazardous substances – a good reason to change. (Photo: licht.de/Signify)

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Assembly halls, lecture theatres and auditoriums

In most schools, the assembly hall is the largest room where students can be brought together. Universities and colleges often have a range of different lecture theatres and auditoriums – the largest of which, in Germany, is known as the “Audimax”, with several hundred seats. Today, all these rooms are equipped with sophisticated technology, but good lighting is a prerequisite for exploiting all the possible room functions.

[34] Light management systems make it easy to switch the lecture theatre lighting from room lighting to lecture lighting. (Photo: licht.de/Zumtobel, photographer Les Pobert)

[35] Assembly halls are multifunctional spaces and therefore require flexible lighting for different usage scenarios. (Photo: licht.de/Bega)

[36] Moving towards the knowledge society. Learners need appropriate lighting that works well with digital equipment. (Photo: licht.de/Signify)

Assembly halls and lecture theatres are used for internal and external events; and are places where teaching staff, students and guests come together on special occasions. The assembly hall is multifunctional and offers space for exams, school assemblies, concerts, year-group and graduation ceremonies. Lectures, talks and meetings of various bodies are held in lecture theatres. Depending on the occasion, a ceremonial or more functional atmosphere may be required, but in which people feel comfortable. Professional lighting design and intelligent lighting management can help here.

Lighting determined by seating arrangement

Auditoriums in older buildings often have no windows and no daylight. Most of them have fixed rows of seats facing the stage. Lecture theatres with level or slightly tiered seating can be illuminated in the same way as classrooms (see page 21). Indirect lighting is recommended in smaller lecture theatres with flexible seating arrangements. Large lecture theatres with steeply tiered seating require good planning: they require uniformity of illuminance, glare limitation and lighting control – all of which must be appropriate for the room.

Room lighting and presentations

Rooms which are used for presentations and performances must be able to be blacked out completely. However, there should be sufficient brightness for students and participants to be able to find a seat and enter and leave the hall quickly and safely. Additional dimmable wall lights serve as orientation aids when the room is darkened. Recessed lights in floors and walls or lighting strips that discreetly illuminate doors and stairs are both functional and visually appealing. Safety lighting and emergency escape route signposting are mandatory (see page 50).

During lectures or events, the room lighting needs to be bright enough to facilitate note-taking. DIN EN 12464-1 specifies an illuminance of at least 500 lux for lecture theatres; the modified value of 750 lux offers even more flexibility. It is important that the lecture and presentation area – including

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The university of the future

Lectures attended by 400 students in a windowless lecture theatre, or overcrowded seminar rooms containing furniture from dozens of years ago – this is how learning is still experienced at most universities today. Modern teaching methods which shift the focus from teacher-centred to project-based learning have little chance of success in such rooms.

Room-in-room designs, however, are ideal for achieving this with their high degree of flexibility and interdisciplinary character. Movable furniture can be used to create smaller units within a large room and allow different didactic methods (involving plenary sessions, chair circles or group tables) to be used. If the screens, too, are movable, this allows the students to set up the rooms as they need. Illustrations of possible room scenarios posted near the entrance serve as inspiration – and will ideally also include lighting recommendations. Many such new learning spaces are characterised by colourful office-type furniture and superior lighting. This makes them similar to the modern office environments with breakout areas, team spaces, touchdown workstations (with no fixed "owner") and focus rooms for concentrated work which are increasingly replacing individual offices.

the lectern, black or whiteboard and experiment bench – is evenly and brightly lit. This must be brighter than the rest of the room. As a general rule, horizontal and vertical illuminance levels should be at least 1.5 times the average illuminance level in the room. Assuming 500 or 750 lux for general lighting, the illuminance on the podium should therefore be 750 or 1,000 lux. For example, pendant luminaires or downlights are suitable for general lighting in lecture theatres and assembly halls, while luminaires with asymmetrical light distribution such as wall-washers are suitable for black or white boards (see page 21). Supplementing the balanced ambient lighting, adjustable spotlights create greater vertical illuminance in the podium area. During presentations, they draw the visitors' attention e.g. to the exhibits (see page 48). It must be possible to dim the entire lighting system at the push of a button.

Lighting management

If the room is used for different purposes, individually switchable and controllable lighting groups can be used to divide the room into separate lighting zones. Light management systems provide for flexible and situation-appropriate lighting. Pre-set lighting scenes such as "Visitors arriving/leaving", "Speech/lecture" and "Image lecture/media presentation" which the presenter can access from a panel near the lectern represent important components here (see page 44). The system must be easy to operate and switching to the relevant scenes must be intuitive. The lighting planner should take this into consideration at an early stage.

[37] Good lighting aids orientation on walkways. (Photo: licht.de/XAL, photographer Kris Dekeijser)

[38] If there is a power failure during a lecture, everyone must be able to leave the room safely. Mains-independent escape sign luminaires above the exit show the way. (Photo: licht.de/Zumtobel, photographer Sigurbjörnsson Refn)

[39] Flexible lighting technology with digitally controllable components turns conference rooms into multifunctional spaces – for factual presentations or events requiring a special atmosphere (Photo: licht.de/Zumtobel, photographer Grober Toon)

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The library

Students spend many hours in libraries for intensive study and reading. An inviting and pleasantly lit environment will make their time there more agreeable and potentially more productive. Good lighting also helps students to maintain high attention levels over a longer period of time.

[40] Good lighting allows users to find their way around libraries, creates good visibility and provides a sense of well-being. (Photo: licht.de/Zumtobel, photographer Jens Ellensohn)

Searching for sources, browsing the Internet, e-learning and consulting old printed works – all these library activities cause visual fatigue. Good lighting can help here. Incident daylight is perceived as particularly pleasant. Artificial lighting which makes use of direct/indirect light distribution (such as from pendant luminaires) ensures uniform illumination throughout the room, avoids the “cave effect” and facilitates focused reading or notebook-based working. Additional mobile luminaires with direct and indirect light components are suitable for illuminating individual work places and meeting areas; these can be supplemented with desk luminaires for a higher lighting level on the work surface. For the reading area, DIN EN 12464-1 recommends 500 to 750 lux for longer periods of research without causing eye strain. Consultation zones are usually separated off to ensure that readers are not disturbed.

In reading rooms, a Human Centric Lighting (HCL) solution can help keep people’s body clocks properly in sync (see page 69).

Modern management systems that dynamically control the artificial light but also make use of incident daylight are used for this purpose. Plenty of daylight is desirable, but blinds need to be used to screen direct sunlight. The lighting control system coordinates the interaction of lights and blinds. The light management system ensures that constant lighting levels are maintained at times when there is little or no daylight.

Computer-based research

All libraries provide computer workstations. They must be ergonomically designed and illuminated to at least 500 lux, without glare or reflection, in accordance with DIN EN 12464-1. Unnecessary visual adaptation and potential eye strain can be avoided if the lighting level around the computer is adjusted accordingly. The same applies to the computer workstation at the issues desk.

Bookstack lighting

Shelves of printed works and media are at the heart of all libraries. The surfaces of all cupboards, bookstacks and walls of books should therefore be well lit. The vertical illuminance must reach down to the lower shelves, allowing the titles on the book spines to be easily discerned from a reasonable distance. Luminaires with asymmetrical light distribution that provide 200 to 300 lux of illumination to the fronts of the bookstacks are suitable for this purpose. The colour and the design of the spine represent further search criteria. Good colour rendering (R_a 80 or more) allows the works to be easily recognised on the shelf. Old books in particular are sensitive to permanent ultraviolet (UV) radiation. They can be protected by LED light sources that emit no UV or infrared radiation.

[41] LED light sources help protect books because they emit no ultraviolet or infrared radiation. (Photo: licht.de/Trilux)

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Luminaires in use

The client, architect and lighting designer need to collaborate closely when selecting suitable luminaires for schools and educational establishments. The decision is based on a range of criteria including technical lighting properties, service life, design, material and lighting control system compatibility.

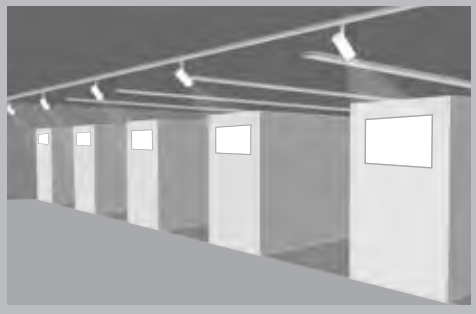
The luminaire is the lighting fixture. It contains components such as a light source, electronics and optics. The LED module, driver, housing with heat sink and optics in an LED luminaire must all be mutually compatible. Schools and educational institutions should use luminaires that are economical, efficient, easy to install and maintain, and they should fulfil high design and quality standards.

Photometric properties
Photometric properties of luminaires include: Luminous intensity distribution (LID) curve, luminous flux, luminous efficacy, light colour, colour rendering and glare limitation. Data sheets provide information on these product values. All luminaires should comply with current standards and bear the ENEC mark. Only dimmable luminaires are suitable for use with lighting control systems. LED luminaires with different LED chips or LED modules can have different spectral components and change their colour temperature with the aid of light control or light management systems.

You can find out more about LEDs in licht.wissen 17.

Continuous-row systems (surface-mounted or recessed) are series-connected and trunking luminaires that are equipped with different optics and anti-glare devices.

Suspended continuous-row lighting systems illuminate the ceiling with their indirect light component and create a pleasant ambience in the room.



Track lighting systems provide flexibility in different room situations. Luminaires or spotlights can be inserted at any point on the track using an adapter, providing light to wherever it is needed.

Wallwashers provide homogenous illumination of walls or board surfaces. They are therefore ideal for light-coloured vertical surfaces.

Surface-mounted luminaires are attached to ceilings or walls. Downlights can be surface-mounted or recessed luminaires.

The fixtures of **recessed luminaires** are flush-mounted in the ceiling, wall or floor. Accordingly, only the light itself can be seen, with the housing of the luminaire becoming practically invisible.

Wall lights are often used for general lighting in corridors and stairwells or for decorative lighting.

Recessed wall and floor luminaires are often used to highlight danger zones.

Pendant luminaires are mounted at a distance below the ceiling and serve as design elements in a room. They provide direct/indirect light distribution and come in a wide variety of designs.

Mobile and desk lamps can be positioned as required to illuminate individual workstations and should therefore be individually dimmable. They are available with direct and indirect light distribution.

Shock-, impact- and ball-proof luminaires: Luminaires in sports halls must be ball-proof so that they do not break and parts do not fall off if hit. Shock- and impact-resistant lights can withstand high levels of mechanical impact.

Daylight systems channel light into the room and protect against glare at the same time. Movable or stationary systems can be installed on the inside or outside of façades, or integrated into the façade or roof surface.

Column luminaires and light pillars provide technical and decorative outdoor lighting. The mounting height and the distance between the luminaires are the factors which determine the illumination of the areas and paths.

Floodlights on appropriately high masts are used for the efficient and homogeneous illumination of outdoor sports fields and other large areas.

Wall and floor luminaires in outdoor areas accentuate facades, plants or objects. They help improve orientation when used for path lighting.

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Conference and training rooms

Learning is an ongoing process. Even after we leave school and complete our initial vocational training, it is important that we continue to acquire knowledge and take further courses if we wish to meet new professional challenges in the future. New knowledge and skills are taught in many areas of work. Conference and training rooms as well as other communication areas need to be considered from a design perspective and equipped with a flexible lighting solution that can be adapted to different situations.

Having the right mix of lighting systems enables effective and flexible lighting for all tasks – large-area ceiling lights for illuminating work and meeting areas; spotlights for accent lighting. Using application-orientated lighting scenes to control all these lighting systems allows maximum flexibility in the use of the rooms.

Companies use such rooms for a wide range of purposes, meaning that they have to fulfil a variety of functions. It must be possible to adapt not only the furniture, but also the lighting to the constantly changing requirements. Sometimes there needs to be a meeting table in the middle of the room; sometimes tables and chairs are arranged in rows for conventional teaching situations; sometimes a theatre-seating arrangement with a podium is required. The focus of the lighting needs to shift in each case. For good lighting design, it is therefore important to discuss the possible types of use with the owner in advance.

No matter what type of event is being held, the normative requirements must be met at all times. It is important to pay particular attention to: light distribution, glare limitation, colour rendering and the light colours used.

“Open” or “closed” room atmosphere

Light influences the way a room is perceived. Luminaires providing both direct and indirect distribution of the light create an open room atmosphere. The indirect light illuminates the ceilings and walls; the direct component illuminates work areas effectively and promotes visual comfort.

Directed light, such as from spotlights, creates strong accentuation and a more closed atmosphere. However, even in this case it is important to ensure sufficient brightness on the horizontal surfaces. The lighting for the lectern and podium can be provided by flexibly adjustable spotlights or downlights. The area around the screen must be completely darkened for LCD-projector or video screen presentations. Basic lighting provides orientation within the room and sufficient light for notetaking, if required.

[42] Conference and training rooms are communication centres containing modern media technology. They are designed for multifunctional use and thus require flexible lighting that is both pleasant and effective. (Photo: licht.de/Radium)

[43] LED lights provide uniform light distribution on the horizontal table surfaces in the training room. (Photo: licht.de/Trilux)

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Staff rooms and offices

Serving as a central workroom and meeting place, the staff room is an important hub. It is a place where lessons are prepared, tests are marked, work is carried out on the PC and teachers exchange ideas with each other. The school management and the school office belong to the administration, whose staff mostly work in individual offices. The visual tasks of such staff members require light which creates a pleasant atmosphere and supports concentrated work.

[44] The eyes must accommodate to the close-up range when working at a computer screen. That is tiring on the eyes. The strain can be relieved by allowing one's gaze to wander at frequent intervals. (Photo: licht.de/Trilux)

Indirect light on the walls and ceilings, and direct, individually adjustable light on the work surfaces creates a balanced lighting effect in the staff room. Well-shielded pendant, floor or desk lamps with direct and indirect light components are suitable here.

Visual performance and visual comfort

Good workplace lighting can be adapted to the respective visual tasks: this ensures good visual performance and visual comfort. The more difficult or critical the visual task, the higher the illuminance needs to be. According to DIN EN 12464-1, 500 lux is the required maintained value for reading and writing. In response to cases in which a user's eyesight has deteriorated, the 2021 update of the standard specifies corresponding "modified" values. This modified value can be 750 or 1,000 lux for reading and writing.

For places with less demanding visual tasks – such as circulation zones and photocopy or file storage areas – the standard specifies 100 to 300 lux illuminance (and modified values of 200 to 500 lux). Lighting systems age and dirt accumulates on them, meaning that the maintained values for illuminance must be increased depending on the maintenance factor.

Avoid glare

The applicable standards and ASR A3.4 Technical Workplace Regulations stipulate the importance of avoiding glare. This applies to discomfort arising both from

daylight and from luminaires. Blinds regulate the amount of daylight entering the room, whereas luminaires must be positioned and adjusted to ensure that their light does not dazzle the user – either directly or indirectly. High-quality systems are designed to limit glare from the outset.

DIN EN 12464-1 specifies basic lighting requirements. In Germany, ASR A3.4 must also be observed. Further information can be found in the Work Place Ordinance and the Occupational Health and Safety Act.

Alternatively, or as a supplement, a lighting system based on Human Centric Lighting criteria (see page 69) helps meets users' individual lighting requirements.

Single offices

A combination of direct/indirect light distribution is the right solution for individual offices and for the school office. Pendant or floor lamps fulfil this task. Located at the individual workstations, they emit a direct downward light component and an indirect component into the room. This promotes uniform light distribution and brightens high ceilings in particular. In work areas close to windows, achieving optimum interplay between natural and artificial light and a good lighting effect is also important. Luminaires are often installed parallel to the window and serve to supplement the daylight. The correct position of the desk and computer is at right angles to the window and the centre of the room. This avoids unwanted shadows. Desk lamps illuminate the work surface directly.

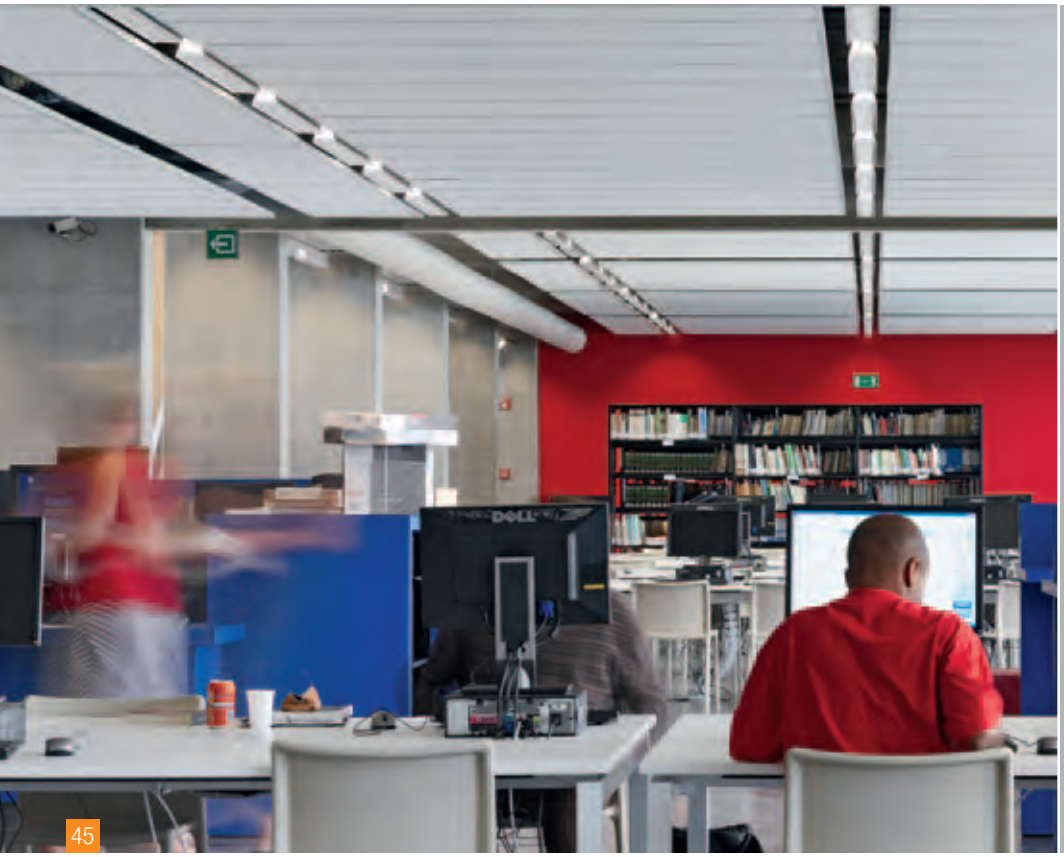
Working at a PC

Different types of DSE are used in schools – in IT lessons, in the school office and in the staff room, for instance. Matt displays are generally relatively insensitive to high luminance levels. 3,000 cd/m2 should not be exceeded. The design and lighting of DSE workstations should avoid irritating glare and reflections (especially reflections on the display) in order to prevent eye strain, loss of performance and, in the worst case, even health problems.

licht.de recommends the use of light management systems: These control and regulate the lighting based on actual demand, occupancy detection, the time of day and the season. Light scenes can thus be pre-programmed for various activities; the scenes are then simple to access. Lighting control systems make lighting more convenient while simultaneously reducing energy costs. They are also a prerequisite for creating a non-visual lighting impact (see page 10).

Issue licht.wissen 04 "Office Lighting: Motivating and Efficient" presents 56 pages of best lighting practices from the office world.

[45] High lighting quality creates optimum working conditions. People who can see well and feel at ease have greater motivation and focus. (Photo: licht.de/Zumtobel, photographer Grober Toon)



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Three lighting concepts

A wide variety of lighting concepts can be used to illuminate office spaces. Here are three common approaches:

- Room-based lighting – creates the same visual conditions at all points in the room and therefore remains flexible, even if the work areas are rearranged.
- Work-based lighting – is ideal in rooms containing multiple work areas where different visual tasks are performed and which therefore require different lighting levels. Furthermore, lighting that is tailored to the needs of the work areas can be customised for each individual user.
- Zone-based lighting – creates certain lighting levels in specific zones within the office (such as a desk) that can be adapted to the visual task or individual requirements.

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Lighting management

Lighting management supports learners of all ages. Lighting management can be used for various purposes ranging from supporting circadian rhythms and creating lighting scenes for specific visual tasks in the classroom through to automatically adjusting the light levels. This takes into account the amount of incident daylight and helps save a great deal of energy.

[46] Good lighting management requires control elements that are simple and intuitive to operate. (Photo: licht.de/Ledvance)

Natural sunlight is the source of all life. Without light, nothing can grow or flourish. Our visual perception, thoughts, imagination and creativity are all dependent on light. Colours reveal their natural brilliance only in daylight. Sunlight also has a major influence on the body's own rhythms. Our sense of well-being, performance and motivation are closely linked to the dynamic ambience created by constantly changing daylight (see page 10). A lighting system planned based on Human Centric Lighting criteria takes this into account.

The German Workplace Ordinance and ASR A3.4 recommend that learning environments and work areas receive as much daylight as possible. A lighting solution that incorporates natural daylight is preferable to one based purely on artificial lighting. This requires sufficiently large window surfaces that let in plenty of light. Daylight can be used effectively and economically if it is properly distributed in indoor areas in a controlled manner. This is best achieved using daylight systems that have been specially developed for this purpose. They distribute natural light evenly throughout the room and bring additional brightness to areas away from windows.

Suitable light sources and light management are ideal ways to counteract the lack of natural light towards the back of the room and in the darker months of the year. Today, contemporary lighting is also an important quality criterion for educational facilities.

The right amount at the right time

The aim is to achieve high lighting quality with the lowest possible energy consump-

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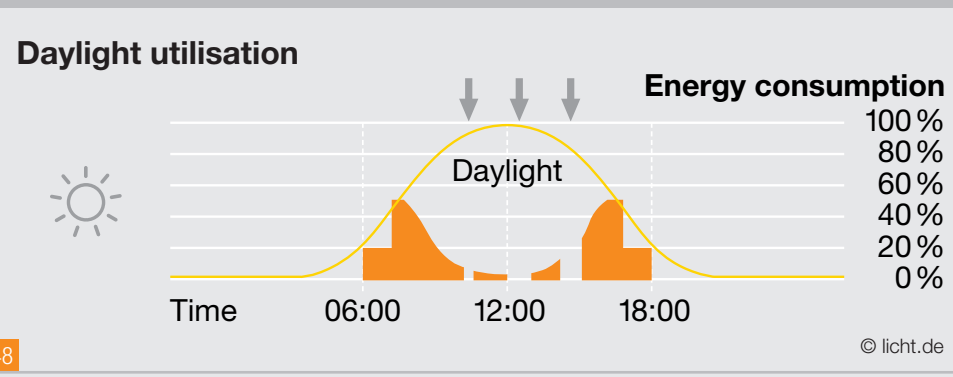

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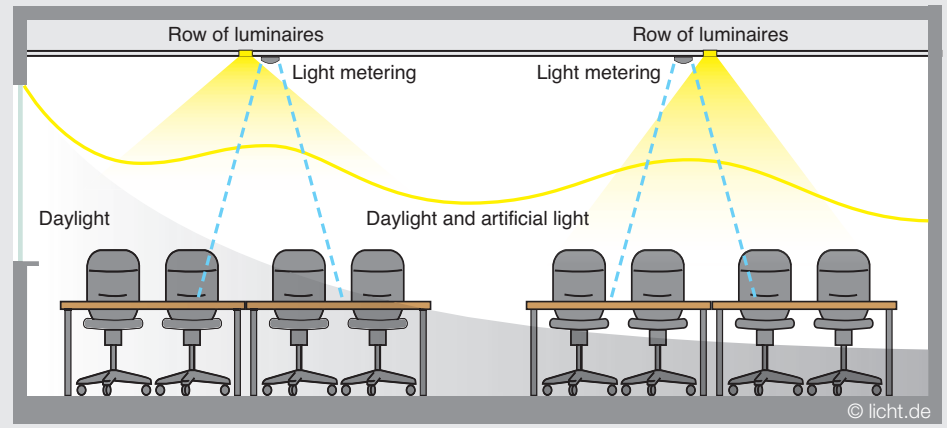

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tion (see Lighting System Design Process page 68). Light management systems which work with daylight sensors only add supplementary brightness to the room with artificial light when necessary.

Occupancy detectors help save energy
Classrooms are not in constant use throughout the day: the lights are often left on and energy is wasted during free periods and breaks. A lighting control system with occupancy detectors solves this problem in a convenient and energy-efficient manner. It switches the lights on and off automatically when people enter or leave the room. The same principle can save a lot of electricity in corridor lighting because the corridors are only rarely used during lessons, as the pupils are in their classes. It is better to dim the lighting to a minimum than to switch it off completely.

Lighting scenes
Light management systems are particularly advantageous in rooms which are used for a constantly changing range of purposes. Lighting scenes tailored to different activities and teaching situations can be called up easily and conveniently via the control display – for example for courses, lectures or media presentations.

Control
Numerous preconfigured and freely programmable control components are available on the market to carry out these functions. They use standardised interfaces such as DALI (Digital Addressable Lighting Interface – wired), Zigbee (wireless), Bluetooth Low Energy (BLE) and others. This also allows them to be integrated into a higher-level building control system, such as a KNX system (see page 69). High-level compatibility between the relevant components facilitates maintenance and raises the overall cost-effectiveness. An emergency lighting system (see page 50) or a central monitoring system, e.g. for signalling errors in individual components, can also be integrated.

Lighting management and lighting scenes should be planned to the same level of detail as the lighting concept itself. They must be intuitive to operate and also allow users to override scenes and automatic functions, such as occupancy detection and light control. Many preconfigured or preconfigurable systems for educational institutions already allow this.

[47] Optimum lecture theatre lighting increases the concentration of the participants. (Photo: licht.de/Ridi)

[48] Occupancy detection helps educational institutions to save a lot of energy and reduce operating costs. The graphic from licht.de shows energy consumption at different times of the day. (Graphic: licht.de)

[49] Light sensors on windows and in the room measure the amount of light and regulate the lighting based on the level of incident daylight. (Graphic: licht.de)

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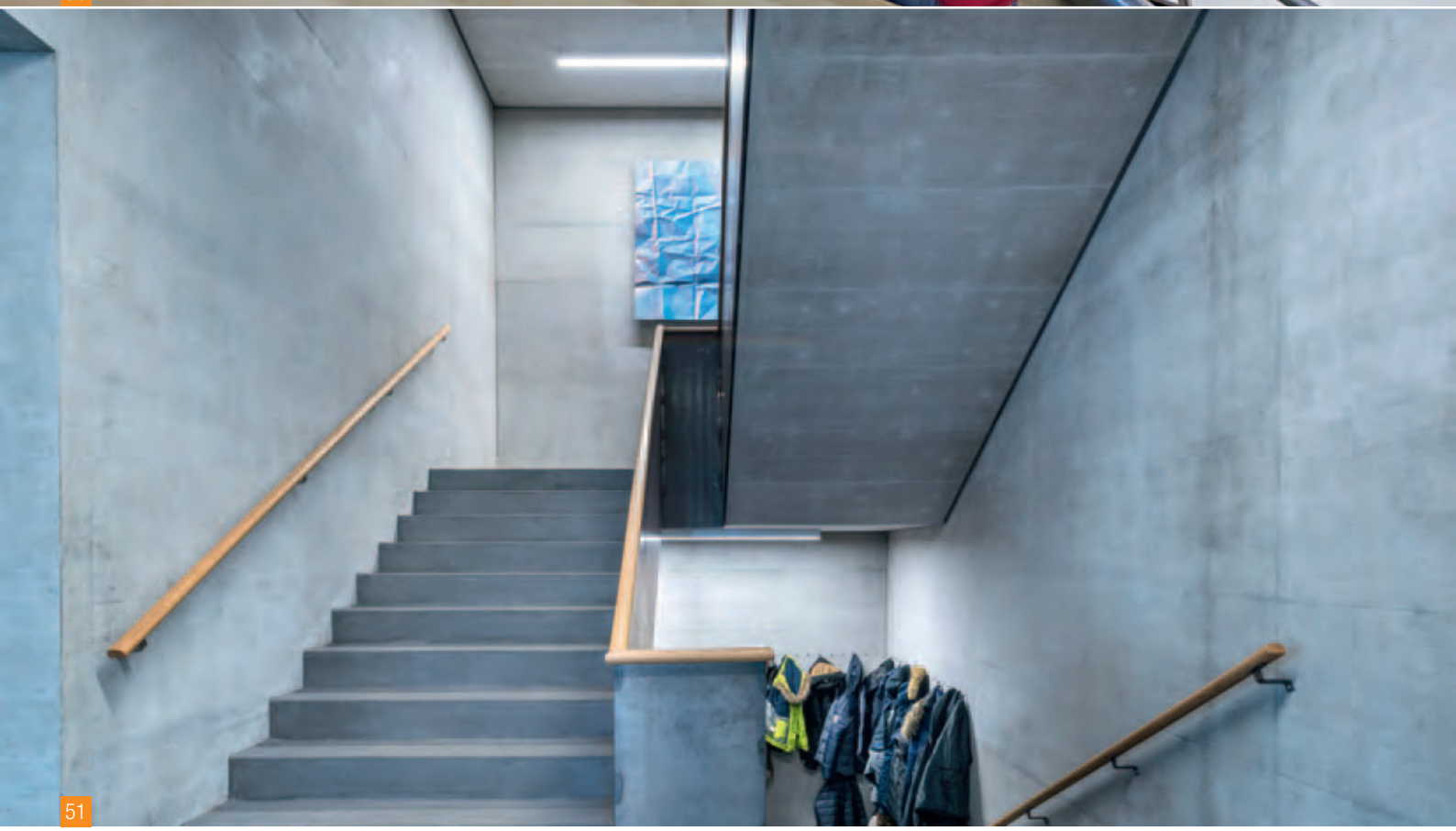

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Orientation and safety in circulation areas

Lighting performs a vital function as an orientation aid in foyers, stairwells and corridors. It provides safety, shows how to access other parts of the building, sets lighting design accents and creates spaces for communication.

The circulation areas in an educational establishment connect the entrance and foyer with the different levels and rooms. Good light facilitates quick and easy orientation but also creates a sense of security and wellbeing Insufficient corridor lighting can produce an unpleasant “tunnel effect”. Dark corners make users feel uneasy. Corridors with bright walls and ceilings look bigger and permit faster orientation. To prevent people from having to move from well-lit areas into dark corridors or vice versa, it is important not only to ensure that the legal standards are met, but also that attention is paid to differences in brightness to neighbouring areas. Efficient, wide-beam luminaires that provide good planar vertical illumination for the wall surfaces represent a good lighting solution. As a general rule, dark floor, wall and ceiling surfaces reflect less light than light-coloured surfaces. The lighting design must then compensate for this by using more energy.

The illuminance in corridors should be at least 100 lux according to DIN EN 12464-1. However, it is also important to take the lighting levels of adjacent areas into account. The lighting level in the circulation routes should be between 1/3 and a maximum of 1/10 of the neighbouring areas; at more than 1,000 lux, the lighting in the corridors must be adjusted to above the DIN value. To ensure that the eye can easily cope with the transition from brighter to darker areas, long corridors with no daylight should either have illuminance levels similar to those in the entrance area or they should only be slightly darker. Here, too, it is important to ensure that the lighting control system does not switch the lighting off completely (see page 44). The minimum requirement for circulation route illuminance is ten per cent of the values in the adjacent rooms.

There are many lights to choose from for corridor lighting: these include surface-mounted or recessed downlights, wall lights or ceiling lights.

Circulation routes as communication zones

Foyers, corridors and stairwells also serve as communication zones and places where students spend breaks. Attractive furniture and good lighting can help make people feel comfortable there. Niches and recreational corners are a good idea because people sometimes use these areas to work or hold conversations.

Notice boards are hung on the walls, which are also used for displaying students’ work and project results. Supplementary, separately switched and individually adjustable asymmetric wallwashers are an appropriate solution here. A power track system with adjustable spots represents a possible alternative.

Depending on the structural design, foyers may also be used for different types of performance. Variable stage spotlights in addition to the separately regulated general lighting are ideal solutions here. A good choice is a simple-to-operate lighting control system with pre-set scenes.

Lighting is not needed around the clock in many school circulation areas, meaning that occupancy detectors – ideally in combination with a lighting control system – can save a lot of energy. If daylight is available, the amount of artificial light can be reduced to the required minimum by means of sensors.

Illuminated stairs help avoid falls

Stairs must be particularly well lit to ensure the safety of users. Glare-free light allows the edges of steps to be clearly recognised. To achieve this, wide-beam wall or ceiling luminaires should be installed parallel to the staircase outside the primary field of vision. It is often sensible to mark steps

[50] An open staircase, adjoined by a spacious entrance area, creates an inviting atmosphere. (Photo: licht.de/Zumtobel, photographer Baan Iwan)

[51] Light from above combined with bright, high-contrast lighting make steps easily recognisable. (Photo: licht.de/Trilux)

with additional orientation lights. These are recessed in the wall or, in the case of wide staircases, built into the risers themselves. Depending on the type of luminaire, every step, or at least every third step, must be illuminated. Wall lights mounted on the stairs must not dazzle people as they walk up or down.

Hard and long shadows should definitely be avoided here. These are created by concentrated beams of directed light. Diffuse light which casts no shadows at all is also undesirable. This is caused by too much brightness coming from the wrong direction; the individual step treads can then no longer be distinguished from one another.

The guideline value for staircase lighting depends on how the staircase is used and should be at least 100 lux in accordance with DIN EN 12464-1. At least 150 lux is required in educational establishments, because large numbers of people can use the stairs at the same time during breaks. Even more convenient and safer is lighting which delivers 200 lux – and which results in only marginally higher operating costs.

Feeling of safety in front of and inside lifts

Many people experience a feeling of unease when they step into a lift. Enclosed spaces create a sense of confinement, and glass lifts in spacious halls can quickly give rise to a fear of heights. The space in front of the lift should therefore have a much brighter and inviting lighting design, with wall lights to the left and right of the lift doors, for example. Bright primary colours work well inside the lift itself. Mirrors and shiny walls and ceilings create a pleasant ambience and give a roomier feel to the lift. Lighting which features a significant component of diffuse light helps avoid stark shadows on users' faces. According to DIN EN 81, lifts must be illuminated to at least 50 lux; DIN EN 12464-1 requires 100 lux inside the lift and 200 lux in front of the doors. Lighting of the same level as that in the lift entrance area and the adjoining corridors has a pleasant effect.

Important: Stairs and corridors also serve as escape routes. Emergency and safety lighting (see page 50) must therefore be planned, installed and regularly maintained in accordance with the relevant standards.

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Exhibitions

Pieces produced in art lessons [52] and photos taken during school trips or projects are commonly displayed in foyers, assembly halls or corridors. The vertical illuminance of the corresponding wall surfaces must be uniform and sufficiently bright.

In addition, the luminaires should be flexible enough to provide optimum illumination of a wide variety of frequently changing objects. Small objects should be illuminated with narrow-beam, flexible and easily adjustable luminaires, while large-format pictures should be illuminated with wide-beam floodlights.

Spotlights on tracks, or surface-mounted or recessed gimbal spotlights are particularly suitable for these lighting tasks. Lamps should be selected which offer good or very good colour rendering of at least R_a 80.

[53] School corridors are also often used as work areas during free periods. (Photo: licht.de/Erco, photographer Jason Mann)

[54] Illuminated steps enable audience members to make their way safely to their seats in rooms that are darkened for events and lectures. (Photo: licht.de/ Barthelme)

[55] Additional step lighting in lecture t heatres aids orientation. (Photo: licht.de/ Zumtobel, photographer Faruk Pinjo)

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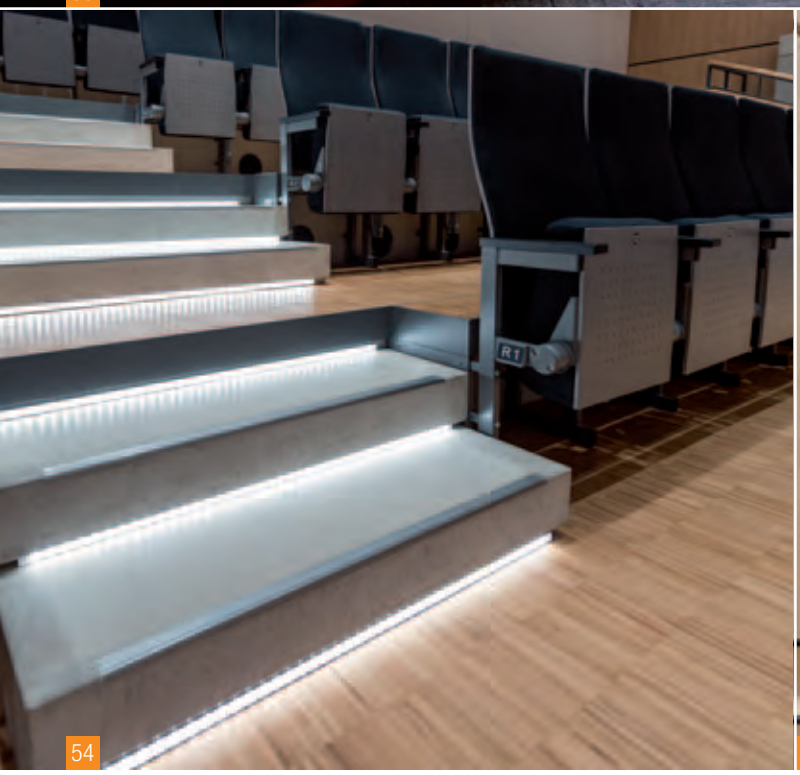

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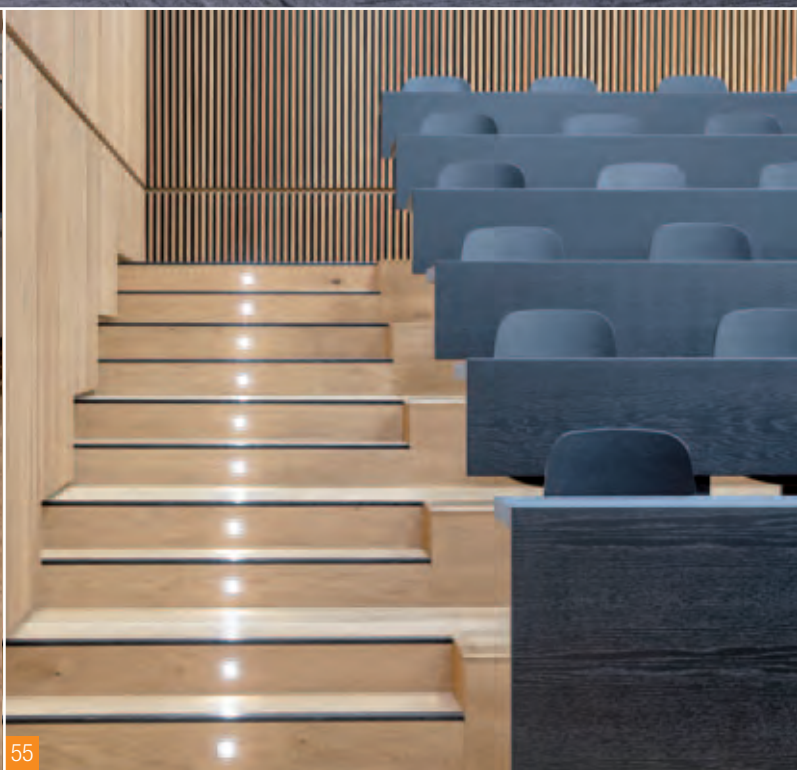

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Safety lighting

If the lights go out during a power outage, panic can easily spread and the risk of accidents increases. Safety lighting connected to a mains-independent power supply helps with orientation, as it ensures a basic level of brightness. This enables people to find their way to the exits quickly and safely, even in an emergency.

Safety lighting systems in public buildings switch on automatically if the mains voltage and general lighting fail. They also help people who are unfamiliar with the building to find their way around and leave it quickly in the event of danger. Safety and escape sign luminaires are used to illuminate and designate escape routes, and to indicate fire extinguishers and first aid facilities, for example.

According to the Model School Construction Guidelines, safety lighting must be provided "... in halls containing escape routes, in critical corridors and stairwells as well as in common rooms with no windows ...". Specialist subject rooms that can be darkened, such as media rooms, are also considered to be windowless recreation areas. Steps must be clearly visible, even in the dark.

Planning and installation

Various standards apply to the planning and installation of the prescribed safety lighting: DIN EN 1838 specifies the lighting requirements and the particular locations that must be illuminated and designated. The illuminance at these points must be at least one lux. In sports facilities, higher values may be required for certain types of sport in accordance with DIN EN 12193. Up to ten per cent of the illuminance level of the general lighting may be necessary for a specified time after a session (up to 120 seconds) to allow participants to finish their sport activity in safety. After this time, the illuminance may drop to one lux.

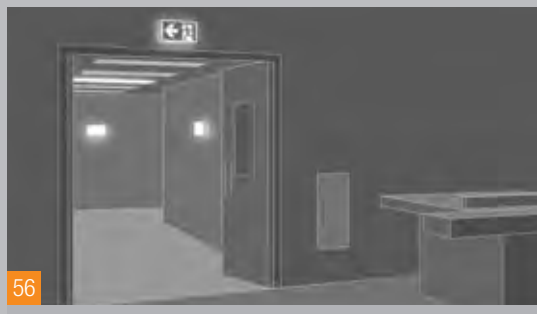
The requirements of the Ordinance on Places of Assembly and DIN EN 1838 apply for all other areas in sports facilities. According to the standard, safety lighting for schools and sports facilities must be designed to function for a duration of three hours, unless otherwise specified by building regulations.

Designation of escape routes at events

The school assembly hall is often used for events outside of lesson times, such as concerts or graduation ceremonies. Escape routes may be changed or blocked for various reasons. Variable-direction escape sign luminaires can alter the temporary escape route signposting with little effort. The building can then be exited safely via an alternative escape route.

Legal aspects

Schools in Germany are governed by the building regulations of the individual federal states. In most states, the respective



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Safety lighting systems

Safety lighting systems [56] in public buildings switch on automatically if there is a mains power outage and the general lighting fails. They also enable people who are unfamiliar with the layout to find their way around the building and leave it quickly in the event of danger. Safety and escape sign luminaires are used for this. They highlight the location of escape routes and safety equipment, thus making it easy to find fire extinguishers, for example, quickly. They help save lives by reducing the risk levels for people in buildings. DIN EN 1838 stipulates horizontal illuminance of at least one lux wide along the centre line of a two metre-wide escape route.

school building guidelines also apply. In addition, rooms and areas that are designed to accommodate more than 200 people, especially in larger schools – such as assembly halls, cafeterias or canteens – are also subject to the Ordinance on Places of Assembly of the respective federal state. The Ordinance on Places of Assembly also applies to some sports facilities and may require safety lighting.

Official specifications, building permits or their fire protection stipulations can give rise to further or alternative safety lighting requirements. It is mandatory to review these on a regular basis.

LED is standard

LED technology is standard in emergency lighting. Its high efficiency means that it requires less battery capacity. Particularly efficient lighting concepts can be realised using special optics to direct the light. The very long service life of LED light sources further reduces maintenance and operating costs. LED emergency luminaires are smaller than conventional emergency luminaires and can be integrated discreetly into the overall architecture of a building.

Find out more about emergency lighting in licht.wissen 10 “Emergency Lighting, Safety Lighting”.

[57] At least one escape sign must be visible from all points on an escape route. (Photo: licht.de/Erco, photographer Jason Mann)

Cafeterias and canteens

People congregate in them to eat, chat, revise, study and discuss – canteens and cafeterias are ideal meeting places. Often designed as multi-purpose rooms, they are places for taking refreshments and for relaxing between classes. They also serve as a meeting point and as a venue for events and celebrations, but also for study and for group work by students and pupils.


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Many people converge on the canteen or cafeteria to eat and relax. Even if they only intend to spend a short time there, guests should feel at ease and be able to relax and take a mental break. An open and friendly room climate allows people to unwind and recharge their batteries. Bright rooms which are flooded with light contribute to this. Generously proportioned and uncovered window surfaces let in as much daylight as possible. This is why canteens are often located on the southern exterior of educational buildings.

Suitable control technology can be used to supplement the daylight with artificial lighting. It is important to have shadow-free lighting which has a good balance of direct and indirect components. This allows people to recognise faces, expressions and gestures easily. The 'modelling' and 'semi-cylindrical illuminance' quality criteria are used to evaluate the lighting solutions. Cafeterias are also places where students can relax and hold conversations. This function is supported by deliberately darker areas, such as lounges and seating areas (see box).

Canteens as multi-purpose rooms
During free periods, the canteen can also be used for private study or by study groups. Separate seating areas are best suited for this and should be illuminated with sufficient artificial light for working. Partition walls create individual zones if the rooms are also used for events, functions or conferences. The lighting design must take this into account. A light management system can be used to provide flexible lighting. It also makes use of energy-optimised lighting technology to control the artificial and natural light levels to ensure standard-compliant and energy-efficient lighting.

General lighting
A wide range of lighting solutions is available to provide economical basic lighting in canteens and cafeterias; these include pendant, surface-mounted and recessed luminaires. Direct and indirect light brightens ceilings and walls, creates a pleasant ambience and invites people to spend time there.

General lighting needs to be flexible so that tables can be moved as required. A system which includes different components for zonal, indirect and direct lighting is ideal for changing the lighting atmosphere. It should also be possible to adjust the colour temperature. Warm light is favoured in everyday school and university situations, while cool white illumination promotes concentration during exams and written tests. DIN EN 12464-1 recommends basic lighting of 200 lux in school canteens. Luminaires used to illuminate terraces or covered areas must be suitable for outdoor use.

Good lighting stimulates the appetite
The light sources should have a high colour rendering index to ensure that the food looks appetising and that the colours of the dishes are clearly recognisable. Also, the lighting for the food dispensing and checkout areas needs to be glare-free.

In summary, canteens and cafeterias demand sophisticated lighting design and technology. It is recommended that detailed advice is sought from an experienced lighting designer – especially if high-quality yet energy-efficient lighting is to be installed which will allow the full multifunctional possibilities of the building to be exploited. Skilful planning helps create spaces that permit different types of use but which remain inviting spots for communication and relaxation.

Seated lounge areas

Seated lounge areas represent a good supplement to the dining tables in canteens and cafeterias. They offer greater comfort and privacy for more discreet conversations and for study and work groups. Room dividers provide additional privacy. Seated lounge areas therefore need their own lighting design. Directed ceiling or pendant lights above the tables provide sufficient light for reading and writing. Wall lights create a pleasant ambience using direct and indirect light.

Service area and counters

The food counter often has an open design to create an inviting atmosphere. Counters, tills and serving areas should definitely have their own lighting design to ensure that meals are presented in an appetising way. The lighting of the counters should be carefully directed and glare-free – with no distracting light reflections. Higher brightness levels promote clear orientation, while superior colour rendering helps customers choose from the dishes on offer. Optimally directed lighting and shiny effects on glass and crockery convey a sense of cleanliness and facilitate the selection process. The till areas require work area lighting of at least 300 lux.


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[58] Light sources with a high colour rendering index make food look natural, stimulate the appetite and make it easier to choose a dish. (Photo: licht.de/Erco, photographer Gustavo Allidi Bernasconi)

[59] Dining tables and steps which can also be used for seating break up the long dining room visually. (Photo: licht.de/XAL, photographer Kris Dekeijser)

[60] People often use cafeterias as places to work and study on their laptops over a latte macchiato. The lighting must therefore also be suitable for reading and DSE work. (Photo: licht.de/Zumtobel)


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Indoor and outdoor sports facilities

Physical effort and fun are key elements when sports are played in indoor and outdoor sports facilities. The participants move quickly, play ball games, do exercises or relaxation activities – making variable illuminance indispensable.

When it comes to lighting, two things are particularly important for meeting the diverse needs of indoor sports facility users. Firstly, ensuring the right blend of lighting factors (including horizontal and vertical illuminance, homogeneity, colour rendering and absence of glare). Secondly, flexible control of the light. Sports events and high-speed competitions require precise perception and high illuminance levels – whereas relaxation exercises call for a calm and subdued lighting atmosphere.

Illuminance

The ASR A3.4 Technical Workplace Regulations and the "Lighting" guidelines of the Federal State and Local Authorities' Working Group on Mechanical and Electrical Engineering (AMEV) apply to school sports. These stipulate at least 300 lux.

If the facility is also used for club sports and competitions, DIN EN 12193 also applies. Higher illuminance levels are required for fast ball sports played with

[61] The faster the sport and smaller the ball, the greater the illuminance required. (Photo: licht.de/Zumtobel, photographer Faruk Pinjo)

small shuttles or balls, such as badminton or table tennis: 300 lux or more is stipulated for vertical illuminance. For competitions and competition training, the recommended values are significantly higher at 500 to 750 lux.

Lighting design and choice of luminaires

The first step in developing a lighting design for an indoor sports facility is to identify the individual sports, because the sport with the most demanding visual requirements should serve as the planning benchmark. The following criteria apply to the choice of luminaires: type of mounting, glare suppression and impact resistance. Depending on the type of ceiling, recessed or surface-mounted luminaires represent suitable options. Pendant luminaires are a good solution, especially in higher halls.

All lights used must be certified as impact-resistant to ensure that they will not be broken if hit by a stray ball. High-grade optics in luminaires help improve visual performance during sport and ensure optimal glare suppression from all viewing angles. From a photometric point of view, planar luminaires are the first choice – these are luminaires with a large light-emitting surface and low surface luminance. Their arrangement should be governed by the sports activities. Good colour rendering is recommended to ensure that colours can be correctly perceived.

[62] Lighting control systems adjust the illuminance to the required level. (Photo: licht.de/Dotlux)

[63] The required lighting level is lower for school sports, but higher for competitions. (Photo: Pixabay/733215)

[64] Floodlights allow training sessions to continue even after dark. (Photo: licht.de/Signify)

[65] Artificial light supplements the daylight entering the sports hall. (Photo: licht.de/Trilux)

[66] Attack and deception – lightning-fast reactions need to be trained in ball sports. Athletes need optimum light conditions for this. (Photo: licht.de/Signify)

Changing rooms

Changing rooms require bright, uniform lighting. Stark shadows are unflattering. At the washbasins, mirror lights provide pleasant illumination of the face. High vertical illuminance levels also help users see inside the lockers. Good colour rendering of the light sources ensures that clothes colours can be accurately recognised. An occupancy control system that switches the lights on and off as required is recommended in changing rooms and sanitary facilities; this provides greater security, saves energy and extends the service life of the light sources.

Outdoor sports facilities

Lighting for outdoor sports facilities is provided in most cases by high-power floodlights mounted on columns. The lighting task is best fulfilled by positioning the columns at the corners, or along the sides, of the playing field. Glare-free and uniform illumination of the playing field is achieved by mounting the luminaires as high as possible. To prevent stark shadows and avoid dazzling the spectators, the floodlights or spotlights need to be arranged so that all points on the playing field are illuminated from at least two directions. The best way to ensure correct lighting for indoor or outdoor sports facilities is to have them carefully planned with foresight by a professional lighting designer.

Information on the lighting of sports facilities is provided in the licht.wissen 08 “Sport and Leisure” booklet.

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Versatile use of multi-purpose halls

Different sports require different lighting levels that are adapted to their particular needs. This places high demands on the lighting itself and on the uniformity of illuminance. The key to versatile use of the space is an intelligent light management system that adjusts the lighting level to the sport being played – and at the same time saves energy. Programmed lighting scenes are accessible at the push of a button, e.g. for simple sports lessons or for competition matches.

It must be possible to switch the lights on and off and dim them separately in individual areas of partitionable halls or in halls in which a stage can be installed. Where daylight is available, brightness sensors can be used to adjust the artificial lighting as required. And to cater for other forms of use – such as school events – luminaires should be connected so they can be switched and dimmed in groups from an intuitively operated control panel.

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Technical terms and standards

To ensure that lighting in schools and other educational establishments is safe, user-friendly and compliant with the relevant standards, a number of important basic rules need to be observed – just as in other workplaces. This section helps explain the standards and technical terms relating to lighting technology and provides a knowledge base for good lighting design.

The planning is based on the Europe-wide EN 12464-1 "Light and lighting – Lighting of workplaces – Part 1: Indoor workplaces" standard published in 2021. The ASR A3.4 Technical Workplace Regulations, published in April 2011, also need to be observed. The "Lighting" recommendations issued by AMEV (Mechanical and Electrical Engineering Working Party of National, Regional and Local Authorities) provides information on the design of lighting systems in public buildings, including educational institutions and sports facilities (see page 54). Normative regulations governing sports facility lighting are contained in DIN EN 12193.

These regulations form the contractual basis for those involved in planning the lighting, however they also contain requirements for the operators of buildings. The requirements are very similar, however they are not identical.

Illuminance
The most important lighting design value is illuminance. Measured in lux (lx), it indicates the amount of luminous flux from a light source which falls on a defined surface. The illuminance can be calculated for any surface in a room, or measured using a lux meter.

A maintained value of 500 lux needs to be provided for writing and reading on horizontal work surfaces. 500 lux is also the stipulated maintained value for panel lighting (see table on page 63). The occupants of a classroom move around for different activities, meaning that the required illuminance levels must be ensured for all areas within the room.

Maintained illuminance
Maintained values for illuminance ($\bar{E}_m$) are mandatory values, however they can be modified. Higher values are advisable if visual tasks are particularly demanding and high-level performance is expected, or if the workplaces only receive little daylight, or the learners have impaired eyesight. DIN EN 12464-1 lists the reasons for the gradual increases in the maintained values. The assessment must ensure that the minimum values as stipulated in ASR A3.4 are observed.

The maintained illuminance values ($\bar{E}_m$) indicate the average illuminance levels that must be achieved at all times – regardless of the age and condition of the lighting system. Over the years, the amount of light available in the room for illuminating visual tasks decreases as luminaires and light sources age and they (or the rooms themselves) become dirtier. To compensate for this, when new systems are to be introduced, they are planned with heightened illuminance values. The decrease is factored into the planning in the form of the maintenance factor: Maintained illuminance = maintenance factor x illuminance on installation.

The maintenance plan, which sets out the time and type of maintenance, must be documented by the planners.

Uniformity
The areas in which the visual tasks and activities are carried out must be evenly illuminated in order to ensure that they can be performed well, but also to create good visual conditions for all activities. Accordingly, the illuminance should not fluctuate too much. The standard specifies the uniformity U_o i.e. the ratio of the lowest illuminance (E_{min}) to the mean value ($\bar{E}$) in the area in question. According to DIN EN 12464-1, this should be at least 0.60 in the visual task area within classrooms and at least 0.10 on walls and ceilings.

[67] Based on the entire service life of the lighting system, LED luminaires represent the most economical option. (Photo: licht.de/Ledvance)

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Immediate surrounding area
The illuminance requirements apply to the specific area of the visual task or activity. To create a transition of brightness to the surrounding area, a boundary of at least half a metre is included around each of these areas. The illuminance of the immediate surrounding area is based on the required values in the area of the visual task. However, the illuminance must not fall below the following levels:

Illuminance in the area of the visual task or activity $\bar{E}_m$ in lux	Illuminance in the immediate surrounding area, in lux
≥ 750	500
500	300
300	200
200	150
≤ 150	same value as in the visual task area
Uniformity U_o in the immediate surrounding area needs to be ≥ 0.40.	

In the rules for workplaces, the surrounding area is normally defined as the entire room, up to the walls minus a band of 50 centimetres around the wall.

Background area
The background is the area beyond the immediate surrounding area. It should not be completely dark, especially in rooms that receive little daylight. The illuminance should not be less than one third of the value in the immediate surrounding area. This applies up to the perimeter of the room, but it must include a boundary of at least three metres around the immediate surrounding area. The background area is not covered in the Technical Workplace Regulations.

Luminance distribution and room brightness
In classrooms and training rooms, the learner's gaze constantly switches between close-up areas (desk) and distant areas (black or whiteboard, teacher). The eyes constantly have to adapt to considerable differences in brightness. This causes fatigue and impacts negatively on visual performance and well-being. However, the differences in brightness should not


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be too small either, otherwise the surroundings will quickly be perceived as monotonous and bland.

Vertical boards and presentation surfaces require at least 500 lux to ensure that anything displayed is also clearly recognisable from the rear seats. Balanced luminance distribution in the visual field also needs to be included in the calculations.

DIN EN 12464-1 also specifies illuminance levels for walls and ceilings. In schools (as well as in offices and hospitals), walls and ceilings are decisive in ensuring a pleasant room brightness which gives classrooms in particular a friendly character.

Further information can be found in the “UGR method – application and limits” ZVEI position paper.

Level ≤ 16, wenn $R_{UG} \leq 16{,}4$
Level ≤ 19, wenn $16{,}5 \leq R_{UG} \leq 19{,}4$
Level ≤ 22, wenn $19{,}5 \leq R_{UG} \leq 22{,}4$
Level ≤ 25, wenn $22{,}5 \leq R_{UG} \leq 25{,}4$
Level ≤ 28, wenn $25{,}5 \leq R_{UG} \leq 28{,}4$

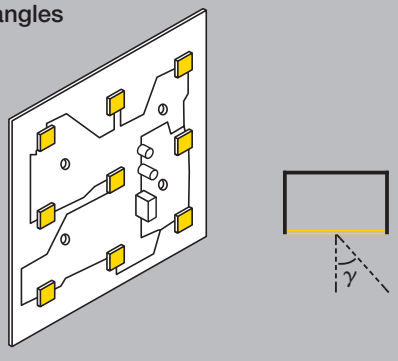
Direct/indirect and direct lighting
Pleasant room lighting is created by luminaires with both direct and indirect light components, which together produce uniform light. Rooms illuminated in this way are usually perceived as more agreeable during longer periods of use. It also reduces the possibility of reflections on glossy magazines and documents. Tables and chairs can be freely arranged with such lighting.

Purely direct lighting represents a slightly more energy-efficient way of supplying the horizontal surfaces with light, however the disadvantage is that the corners of the room and the ceiling can remain relatively dark.

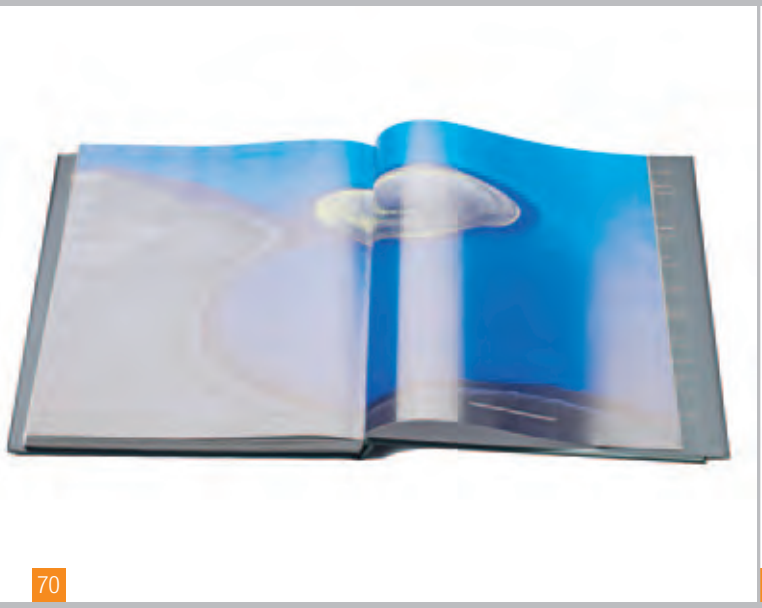
Direct glare: avoid discomfort glare
Glare is a disturbance in the direct field of vision caused by very bright surfaces, bright light sources or windows. It impairs perception and visual performance – although in some cases only as a subconscious disruptive factor. Such discomfort (or psychological) glare can lead to eye strain and concentration errors. The UGR (Unified Glare Rating) method is used to quantify it. This takes into account all the luminaires in a lighting system which, in conjunction with the brightness of walls and ceilings, can create glare. The UGR value for certain room sizes is determined using tables provided by luminaire manufacturers for their products. It must not exceed the R_{UG} limit (R_{UGL}) specified in the standard.

Prevent direct glare caused by excessive luminance from light sources: Shield and limit the luminance of the light source
Light protection systems can be used to darken windows. In luminaires, the irritation caused by the luminance of a light source can be reduced in two ways: the light source can be shielded, or the intrinsic luminance of the light source itself kept below a given limit value. The minimum shielding angle and maximum luminance at specific beam angles are specified in the standard, as shown in the following table:

Maximum average luminance of a luminous optical element at specified beam angles



Beam angle γ	Maximum average luminance of a luminous optical element kcd m^{-2}
$75° \leq \gamma < 90°$	≤ 20
$70° \leq \gamma < 75°$	≤ 50
$60° \leq \gamma < 70°$	≤ 500



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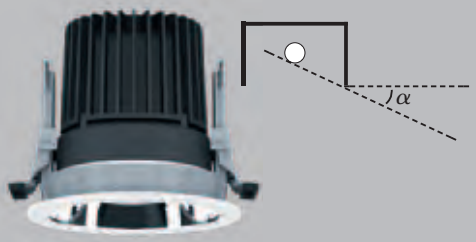
Minimum shielding angle for specified luminance levels of light source



Luminance of light source kcd m^{-2}	Minimum shielding angle α
20 bis < 50	15°
50 bis < 500	20°
≥ 500	30°

Reflected glare

Light reflections on books or documents can be distracting. They are caused by reflections from bright surfaces, especially the light from luminaires. Particular attention should be paid to the luminaires in reading areas. Here, there should be no reflections caused by excessive luminance levels from the luminaires.

The following measures can prevent or limit veiling reflections and reflected glare:

- Correct positioning of work areas in relation to luminaires, windows and skylights – preferably with incident light from the side
- Possibility to shade windows and skylights
- Luminaires with a large luminous area that is not too bright
- Luminaires with a high proportion of indirect light components
- Suitable finishes (matt surfaces)
- Light ceilings and walls

Room lighting

People and objects should be immediately discernible in a room. This facilitates good communication and perception. Vertical light components are therefore required throughout the room, especially for the work areas.

DIN EN 12464-1 specifies maintained values for cylindrical illuminance ($\bar{E}_{m,z}$) which are based on the vertical illuminance for the walls.

Shadows and modelling

Without light we cannot make out objects; without their shadows they appear merely as two-dimensional figures. Only with the right distribution of light and shade can faces and gestures, surfaces and structures be properly discerned. Such light and shade is what makes spatial vision possible in the first place. It allows distances to be estimated, thus facilitating orientation. In lighting technology, modelling means creating a balance between direct lighting with directional components and indirect, more diffuse room illumination. This balance aids spatial and three-dimensional perception.

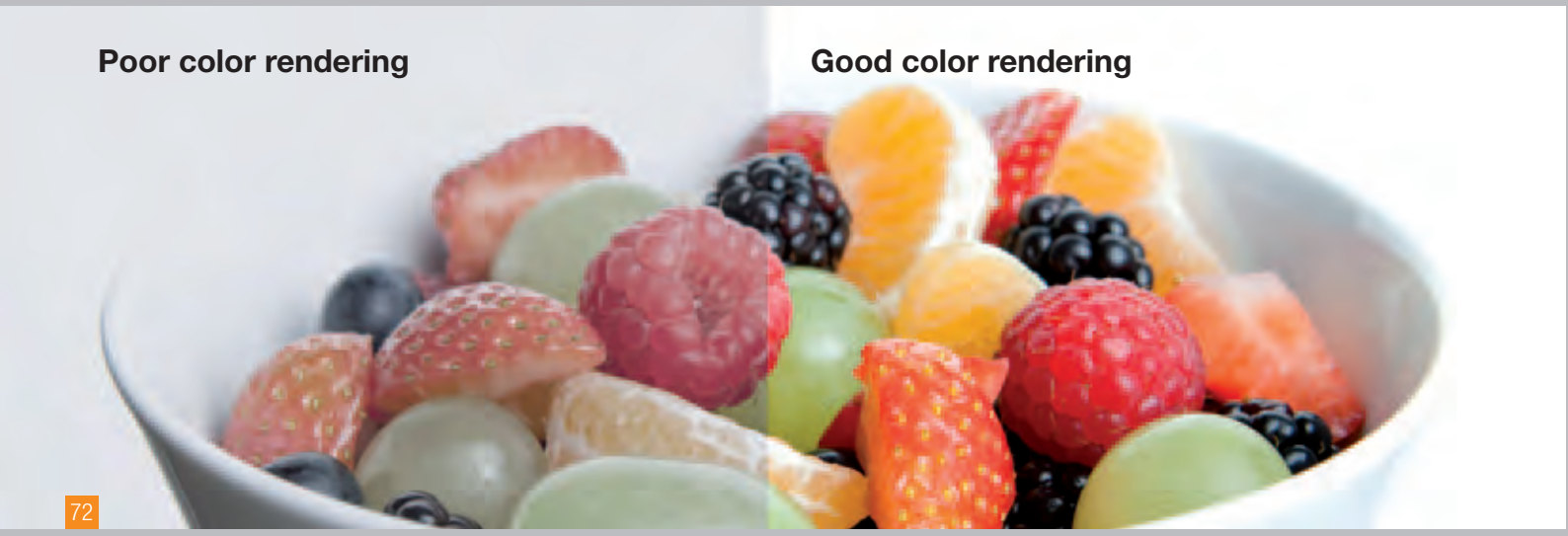
Modelling is defined as the relationship between cylindrical (E_z) and horizontal (E_h) illuminance at a particular point and should be within a value range of 0.30 and 0.60.

When playing fast ball games such as tennis or squash, we need sufficient shade to be able to discern and assess trajectory and speed. However, stark shadows can also be irritating: to prevent this when writing, for example, the light should come from the left for right-handers.

Care should also be taken to avoid multiple shadows, which can cause confusing visual phenomena. This can happen when multiple small points of directed light are used to illuminate an object, causing it to cast multiple shadows with sharp edges.

[68+69] Reflected glare and veiling reflections can interfere with work at a PC screen. (Photo: lcht.de/Signify)

[70+71] Reflections on glossy paper can cause glare. Correctly positioned luminaires with direct and indirect light components prevent disruptive effects. (Graphics: licht.de/Trilux)



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Colour rendering
Only when colours are reproduced realistically do they appear natural and allow students to view their study materials properly. The quality to which colours are reproduced under artificial lighting is expressed by the colour rendering index (R_a). An R_a value of 100 means that the colours of an object are identical to how they would be perceived in natural light. Depending on their type and quality, LED light sources can now achieve very good colour rendering values.

Light colours
The light of each white light source has its own so-called light colour. It is described in terms of its colour temperature, measured in kelvins (K). The higher the temperature value, the cooler the light colour appears.

The light colours of light sources are divided into three groups:
- Warm white (ww) light below 3,300 K is perceived as friendly and pleasant.
- Neutral white (nw) light between 3,300 and 5,300 K creates a rather more functional lighting atmosphere.
- Daylight white (dw) light above 5,300 K appears cold and austere.

Light colour and colour rendering result from the spectral distribution of the wavelengths of light from a given light source.

Flicker and stroboscopic effects
Fluctuations in brightness can occur in LED light sources, especially during dimming. These manifest themselves in flicker, a rapid and perceptible light effect which can also take the form of still images which are created when rapidly moving objects are illuminated. Such stroboscopic effects must be avoided for safety reasons. Manufacturers must ensure that their products comply with the limit values for perceptible interference (see page 68).

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[72] The light source must have good colour rendering in order to reveal colours accurately. (Photo: iStock, angiephotos)

[73] Circulation area with added value: Steps invite students to take a break or do some climbing. (Photo: licht.de/Zumtobel, photographer Jesper Malmkvist)

[74+75] For right-handed people, the light should shine onto the work surface from above left. This avoids unwanted shadows. (Graphic: licht.de/Trilux)

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Extract from DIN EN 12464-1

Location of visual task/activity		$\bar{E}_m$ required	$\bar{E}_m$ modified	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx	Specific requirements
34.5.1	Conference and meeting rooms	500	1.000	0,60	80	19	150	150	100	It should be possible to adjust the lighting.
34.5.2	Conference table	500	1.000	0,60	80	19	150	150	100	It should be possible to adjust the lighting.
43.1	Play rooms	300	500	0,40	80	22	100	100	75	Diffuser lamp shades should be used to avoid high luminance levels when viewed from below.
43.2	Nurseries	300	500	0,40	80	22	100	100	75	Diffuser lamp shades should be used to avoid high luminance levels when viewed from below.
44.1	Classrooms	500	1.000	0,60	80	19	150	150	100	Lighting should be adjustable for different activities and lighting scenarios. In classrooms used by small children, the required $\bar{E}_m$ of 300 lx can be achieved by dimming. Ambient light should be taken into account.
44.2	Auditorium, lecture theatres	500	750	0,60	80	19	150	150	50	The lighting should be adjustable for various A/V requirements.
44.4	Blackboards, greenboards and whiteboards	500	750	0,70	80	19	-	-	-	Vertical illuminance levels. Specular reflections should be avoided. Teachers and speakers must be illuminated with sufficient vertical illuminance.
44.8	Demonstration bench in lecture theatres	750	1.000	0,70	80	19	-	-	-	
44.11	Rooms exclusively for computer work	300	500	0,60	80	19	100	100	75	DSE work: the lighting should be adjustable.
44.12	Art rooms	750	1.000	0,70	90	19	150	150	100	It should be possible to adjust the lighting. Ambient light should be taken into account, 4.000 K ≤ T_{cp} ≤ 6.500 K
44.14	Practical rooms and laboratories	500	750	0,60	80	19	150	150	100	It should be possible to adjust the lighting. Ambient light should be taken into account.
44.15	Handicraft rooms	500	750	0,60	80	19	150	100	100	It should be possible to adjust the lighting. Ambient light should be taken into account.
44.16	Teaching workshops	500	750	0,60	80	19	150	150	100	It should be possible to adjust the lighting. Ambient light should be taken into account.
44.17	Preparation rooms and workshops	500	750	0,60	80	22	150	150	100	It should be possible to adjust the lighting. Ambient light should be taken into account.
44.18	Entrance halls	200	300	0,40	80	22	75	75	50	
44.19	Circulation areas, corridors	100	150	0,40	80	25	50	50	30	Horizontal illuminance at floor level
44.20	Stairs	150	200	0,40	80	25	50	50	30	Horizontal illuminance at floor level
44.21	Common rooms	200	300	0,40	80	22	75	75	50	
44.22	Staff rooms	300	500	0,60	80	19	100	100	50	
44.23	Library: Bookstacks	200	300	0,60	80	19	-	-	-	Vertical illuminance for bookshelves. The R_{UGL} value does not apply to dedicated bookshelf lighting.
44.24	Library: Reading area	500	750	0,60	80	19	100	100	50	Public areas – libraries
44.25	Storage rooms for teaching materials	100	150	0,40	80	25	50	50	30	
44.26	Sports halls, gymnasiums, swimming pools	300	500	0,60	80	22	75	75	30	These requirements only apply to schools. The specific requirements of DIN EN 12193 apply for training and competitions outside of school use.
44.27	School canteens	200	300	0,40	80	22	75	75	50	
44.28	Kitchen	500	750	0,60	80	22	100	100	75	

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Lighting for schoolyards and parking facilities

The schoolyard can be used as a leisure, sports and play area in all weathers – in some places even after school has finished. Good lighting ensures safety and highlights the architectural features.

Safety is the most important criterion when planning lighting for the outdoor areas of schools and other educational establishments. The lighting must highlight risk areas such as entrances and exits, but also steps and potential obstacles. This requires sufficient brightness on horizontal and vertical surfaces as well as glare-free and uniform light. Stark shadows should be avoided as far as possible, which will facilitate orientation and permit good facial recognition.

Steps lighting

Steps and obstacles stand out vividly when a good balance is created between light and soft shadows. Long cast shadows should be avoided because steps can then be misjudged, raising the risk of accidents.

Select robust luminaires

Luminaires in outdoor areas must fulfil exacting requirements – in terms of temperature tolerance and impermeability to water, insects and dust. The minimum requirement here is protection class IP 44. Ball-proof and vandal-proof luminaires are particularly hard-wearing and can withstand the rough and tumble of everyday school life.

Column and bollard luminaires are suitable for outdoor areas, as are wall lights and recessed ground lights. Covered areas can be attractively illuminated with surface-mounted or recessed ceiling luminaires. Luminaires with directional reflector systems guide the light to where it is needed – without creating irritating glare or light pollution.

Selected areas, such as groups of trees or façades, can be accentuated in appropriate light colours. A light management system can take care of multiple tasks simultaneously. The lighting can be switched on or off based on the time of day and season, or on the presence of people; it can also effect changes of colour temperature and illumi-

[76] Room for movement: Luminaires in outdoor areas of schools should be robust and ball-proof. (Photo: licht.de/Trilux)

nance as required. This also protects nocturnal animals and insects.

Schoolyard of the future

More and more schools – especially all-day schools – are attaching greater importance to their outdoor areas. Schoolyards are places where young people come together and discover the importance of shared experience and recreation. At the same time, they serve as “green classrooms” and as potential locations for extracurricular activities and events. A seamless transition between the schoolyard and an adjacent park can also improve the appeal of the area within the neighbourhood. This turns schools into openly accessible urban features. Digitally controlled outdoor and pathway lighting can be easily adapted to new requirements.

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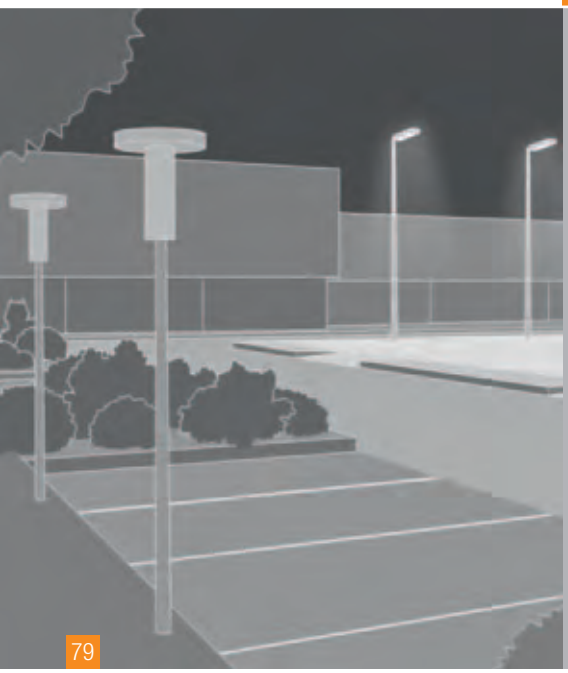
[77] Danger zones in schoolyards such as entrances and exits, as well as steps and obstacles, must be accentuated by the lighting. (Photo: licht.de/Zumtobel, photographer Isabelle Bacher)

[78] Well-illuminated racks make bikes easily visible in the dark, and locks easier to use. (Photo: licht.de/Leccor, Hausrugger Fotografie – Wolfgang Lehner)



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Car and bicycle parks

Safety is of paramount importance here: car parks are circulation areas. They are used by pedestrians, cars, motorbikes and bicycles alike. The greater the volume of traffic, the higher the risk of collision. Good lighting reduces the risk of accidents. Well-lit roadways, paths and squares make it easier for people to find their way around, to spot vehicles, people and obstacles and to protect themselves from crime. Lighting also highlights danger zones such as entrances and exits. The required (maintained) illuminance set out in DIN EN 12464-2 depends on traffic frequency: at least 20 lux is needed for heavy traffic, 10 lux for medium and 5 lux for light traffic levels. It is important to ensure that the lighting extends to peripheral areas. Luminaires must also be shielded.

The transport transition and the increased popularity of cycling as a sustainable means of transport mean that bicycle parking facilities are gaining in importance, and should be adequately lit at dusk and in the dark. Lighting in inaccessible areas should be dimmed or switched off at night. How the luminaires are arranged is determined by the spacing of the individual fixtures. Minimum lateral clearances allow cyclists to manoeuvre their bikes without difficulty: if the bicycle stands are all at the same level, a distance of 70 centimetres is appropriate. 50 centimetres is sufficient if the front wheels alternate between high and low slots (height difference 20 to 35 centimetres). If the parking rows are diagonal, it is not the distance between the fixtures that is decisive, rather the distance between the bicycles themselves. Illuminated bike racks with integrated light strips make it easier to see when opening cycle locks.

Literature

[1] **Zukunftsinstitut,** Bildung im Zeitalter der Wissensexplosion, Megatrend Dokumentation, 2012

[2] **Montag Stiftung Jugend und Gesellschaft,** Schulen planen und bauen 2.0 Grundlagen, Prozesse, Projekte, 2nd edition 2012

[3] **Seydel, O.,** Pädagogische Perspektiven für den Schulbau, 2012

[4] **Seydel, O.,** Das kleine Schulbaulexikon, 2018

[5] **Stadt Köln,** Planungsrahmen für pädagogische Raumkonzepte an Kölner Schulen, 2016

[6] **Christoph Schierz,** Leitfaden zur Beleuchtung von Unterrichts- und Vortragsräumen, LiTG 2013

[80] Shrewd lighting of the long school corridor opens up the space and avoids a so-called tunnel effect. (Photo: licht.de/XAL, photographer Kurt Kuball)

[81+83] Light is essential for visual perception. (Photo: licht.de/Signify)

Studies

[7] **Cheryan S.,** Designing classrooms to maximize student achievement, 2014

[8] **Heschong-Mahone-Group,** Daylighting in schools: an investigation into the relationship between daylighting and human performance, 1999

[9] **Baloch R.M.,** Daylight and school performance in 2670 european schoolchildren, 2021

[10] **Singh P.,** Impact of lighting on performance of students in Delhi schools, 2020

[11] **Lekan-Kehinde M.,** Impact of lighting on children's learning environment, 2021

[12] **Llinares C.,** Do attention and memory tasks require the same lighting – a study in university classrooms, 2021

[13] **Hatori M.,** Global rise of potential health hazards caused by blue light-induced circadian disruption in modern aging societies, 2017

[14] **Russart KLG.,** Light at night as an environmental endocrine disruptor, 2018

[15] **Mahajan K.,** Effects of partial sleep deprivation on braking response of drivers in hazard scenarios, 2020

[16] **Uehli K.,** Schlafprobleme und Berufsunfälle, 2015

[17] **Xun H.,** Feeling disconnected from others: The effects of ambient darkness on hedonic choice, 2018

[18] **Schaller M.,** Fear of the dark-interactive effects of beliefs about danger and ambient darkness on ethnic stereotypes, 2003

[19] **Randler C.,** Chronotype in children and adolescents, 2016

[20] **Eid B.,** Evaluation of chronotype among children and associations with BMI, sleep, anxiety, and depressione, 2020

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Overview of standards

AMEV (Arbeitskreis Maschinen- und Elektrotechnik staatlicher und kommunaler Verwaltungen) Beleuchtung, Hinweise für die Beleuchtung öffentlicher Gebäude, 2023

ASR A3.4 Technische Regeln für Arbeitsstätten – Beleuchtung

DIN EN 12193 Light and lighting – Sports lighting

DIN EN 12464-1 Light and lighting – Lighting of workplaces, Part 1: Indoor work places

DIN EN 12464-2 Part 2: Outdoor work places

DIN/TS 5031-100 Optical radiation physics and illuminating engineering – Part 100: Melanopic effects of ocular light on human beings – Quantities, symbols and action spectra

DIN/TS 67600 Complementary criteria for lighting design and lighting application with regard to non-visual effects of light – this document describes cause-and-effect relationships for the melanopic effects of light that can be used in lighting design.

[82] In the case of target sports in multi-functional sports facilities, all eyes are focussed on one thing: the target. High vertical illuminance levels are important for accuracy here. (Photo: licht.de/Dotlux)

Glossary

Building Information Modelling (BIM) The BIM planning method enables all those involved in the construction work to collaborate effectively – on the basis of digital 3D models. These contain all the building data and can be processed digitally for all purposes such as planning, simulation, calculation and tendering, and for the construction and operation of the property.

Chronotype Each person's internal clock defines their chronotype. The two primary types are early risers (larks) and late risers (owls), with all gradations in between. A person's chronotype is also influenced by their gender and age.

Circadian rhythm Light synchronises the human biological rhythm within a period of approximately 24 hours (Latin: circa = approximately, dies = day). The most prominent example is the wake-sleep rhythm.

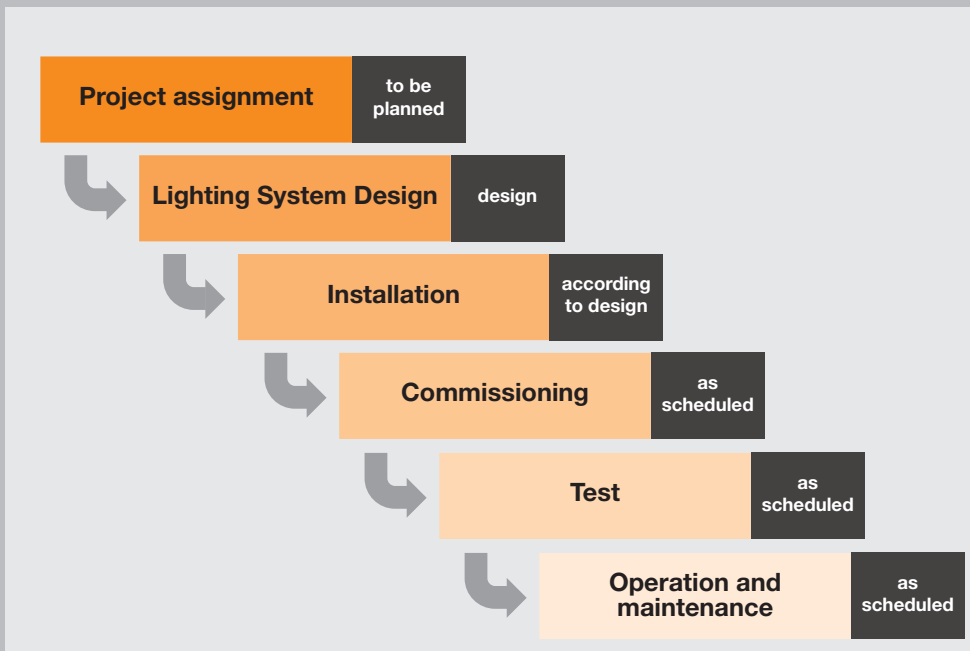
DALI (Digital Addressable Lighting Interface) is a standardised interface for controlling electronic control gear via digital signals. The DALI interface can control many luminaires individually with a small number of cables, including over long distances.

DALI networks can also be easily integrated into higher-level building systems.

Degradation, in lighting technology, is the reduction in luminous flux in LED light sources. Under normal circumstances LEDs do not break down, but their light output decreases over time. The ageing process can be accelerated by adverse operating conditions, such as overheating.

Flicker and pulsating light can cause visual fatigue and headaches, and increase the risk of accidents. High-grade electronic control gear (ECG) prevents flicker and pulsation, or reduces them to a minimum.

Li-Fi stands for Light Fidelity. It is a form of rapid data transmission using LED light: data is transmitted in the form of codes to a photocell – in a notebook or tablet, for example – by imperceptibly switching



[84] The lighting system design process provides structured support for the overall lighting design: Project assignment – Planning – Construction – Operation. (Graphic: licht.de)

the light source on and off very quickly. Optical data transmission is a very secure method which is protected against unauthorised access due to the visual connection which is required between the devices.

Human Centric Lighting (HCL) is a lighting concept that places as much emphasis on the biological and emotional factors as on the visual aspects of perception and visual comfort (see definition in the introduction to licht.wissen 21 “Guide to Human Centric Lighting (HCL)” or in the ZVEI position paper on Human Centric Lighting). It is also referred to as “integrative lighting”.

KNX is an intelligent BUS system for electrical installations. It links together all home and building system components, and is used for the intelligent control of lighting, heating and alarm systems, for example.

Lighting System Design Process (LSDP) is a planning process for lighting systems. It is described in the technical specification DIN SPEC 67503. Fundamental planning considerations regarding high-quality and energy-efficient lighting are incorporated into the installation, commissioning and operation of a lighting system, thereby enabling it to fulfil the user’s requirements to the fullest extent.

It also includes a risk analysis for safety lighting. The process allows regulatory measures to be implemented and test requirements to be developed.

Types of school building

Corridor-type schools are based on the classic floor plan commonly used in the last century: rows of classrooms are arranged along corridors.

Atrium-type schools have a modern layout: a large hall, usually located in the centre of the building, extends from the ground floor to the upper floor; it is surrounded by the different storeys in a horseshoe or ring shape, usually connected by a gallery.

Types of school in Germany

There are four types of all-day schools in Germany today: In the “voll gebundene” type of all-day school, all pupils take part in all-day educational programmes; in the “teilweise gebundene” type, only individual classes/year groups participate; in the “offene” type, individual pupils attend for one semester / a complete school year, or only on individual days. “Ganztägige” schools do not have an official all-day programme, but they offer afternoon lessons and extracurricular activities.

Inclusion is a pedagogical approach based on the principle of valuing and recognising diversity in children’s education and upbringing.

[85] The right light creates optimum conditions for teaching and learning. (Photo: licht.de/Signify)

licht.de publications

licht.wissen 21

Guide to Human Centric Lighting (HCL)

Booklet 21 contains 36 pages of background knowledge on chronobiology and describes how light can influence our sleep rhythm and our mood. Exemplary solutions are presented for four typical applications – Office, School, Industry and Home.

[licht.wissen 01] licht.wissen 01 provides 60 pages of basic information on modern lighting technology presented in a comprehensible and impartial way. This is the first of a total of 21 “licht.wissen” brochures.

[licht.wissen 09] 40 pages on modernisation in commercial, industrial and administration buildings, with numerous practical examples – including for classrooms. It reveals how modernisation saves energy while improving lighting quality.

[licht.wissen 10] 52 pages on emergency and safety lighting: booklet 10 provides information on relevant standards and regulations, explains lighting and electrical requirements and presents numerous application solutions.

[licht.wissen 17] This booklet provides an introduction to the fundamentals of LED lighting technology. It contains 56 pages describing various applications and setting out quality features and key figures: values, costs and environmental aspects.

licht.wissen – by post or available as a free PDF download from www.all-about-light.org

01 Lighting with Artificial Light (2016)
02 Learning in a New Light (2024)
03 Roads, Paths and Squares (2014)
04 Office Lighting: Motivating and Efficient (2012)
05 Industry and Trade (2018)
06 Shop Lighting – Attractive and Efficient (2011)
07 Light as a Factor in Health (2012)
08 Sport and Leisure (2010)
09 Refurbishment in Trade, Commerce and Administration (2014)
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18 Good Lighting for Museums, Galleries and Exhibitions (2007)
19 Impact of Light on Human Beings (2014)
20 Sustainable Lighting (2014)
21 Guide to Human Centric Lighting (HCL) (2018)

The booklets are available in English as PDF files. Free download at www.all-about-light.org

All about light!

Impartial information
licht.de provides information on the advantages of good lighting, with the industry initiative offering an abundance of material on every aspect of artificial lighting and its correct usage. The information is impartial and is based on the relevant DIN and VDE technical guidelines.

licht.wissen
The “licht.wissen” series comprises 21 titles. Featuring many lighting examples, these themed booklets explain the basics of lighting technology and show exemplary solutions. The lighting information contained in all of these booklets is of a general nature.

licht.forum
The licht.de periodical “licht.forum” addresses current issues relating to lighting applications and presents the latest lighting trends. It is a compact specialist periodical published at irregular intervals.

www.licht.de
The industry initiative also presents its lighting information on the Internet. At www.licht.de, architects, designers, lighting engineers and end users have access to around 5,000 pages of practical tips, details of a host of lighting applications and up-to-the-minute information on light and lighting. An extensive database of product overviews provides a direct link to manufacturers.

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licht.wissen 02

Learning in a New Light

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