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Industry and Trade

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Editorial

All workplaces, from offices and laboratories through to production halls and external warehouses, must meet numerous health and safety requirements. Good lighting is a fundamental prerequisite for this. It should provide support for any visual processes and protect employees from accidents and health hazards. But light can do much more: it can influence physiological processes – such as biological rhythms – and thus have an impact on performance and psychological well-being. It has both short-term and long-term effects that can support concentration, performance and well-being. For the statutory accident insurers and the German Social Accident Insurance organization (DGUV), workplace lighting is therefore an important occupational health and safety factor.

"Human Centric Lighting" (HCL) systems are available that – now more than ever – put people and their needs first. In addition to work and performance, the focus is increasingly on the employees themselves and their health and well-being. "Healthy workplaces" are created by considering all facets of lighting.

The requirements for workplace lighting are laid down in the German Ordinance on Workplaces (ArbStättV) and are specified in the Technical Rules for Workplaces – "Lighting" (ASR A3.4). These are supplemented in relevant standards, such as the DIN EN 12464 series of standards for the planning and implementation of lighting systems.

Lighting requirements are usually given as minimum values to be ensured while work is being performed. The disadvantage is that, in practice, these are then often used as the sole basis for planning. New technologies offer many valuable solutions for optimization while simultaneously improving energy efficiency. Accident insurer publications, such as DGUV Information 215-210 "Natural and artificial lighting for workplaces", explain the interrelationships and provide help with regard to implementation.

Lighting technology has changed dramatically over the past decade. Today, conventional lamps are being replaced by efficient LED chips, the success of which has led to the development of new control options that not only save a lot of energy, but also provide greater lighting comfort and flexibility. Modern lighting designs take into account particular environments by using intelligent lighting control based on daylight sensors, e.g., to provide more light for older employees or higher illuminance levels for workplaces with exacting visual requirements. Employers and employees alike benefit from these advances in lighting technology.

This new licht.wissen 05 booklet provides comprehensive information on modern industrial lighting and presents a range of potential applications and practical examples. I wish entertaining and instructive reading for all those responsible for providing good lighting in the workplace.

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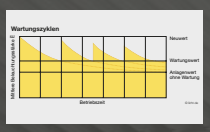
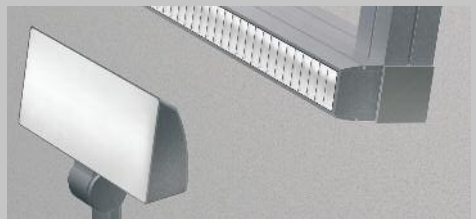


Lighting Topics



Good light, good work

A modern, highly efficient lighting system saves a lot of energy. Of even greater significance, however, is the positive effect which high quality light has, because light is essential for many physiological processes and contributes significantly to people's well-being, health and performance. Good lighting is therefore a worthwhile investment, not least in industrial workplaces.

Germany is currently third in the worldwide ranking of manufacturing countries – a position which is not likely to change in the coming years, according to a forecast by the Deloitte management consultants in their Global Manufacturing Competitiveness Index 2016. Industry is a major employer: according to the Federal Statistical Office, more than 5.4 million people work in an industrial company with a workforce of more than 50 employees (April 2017). In addition, considerable numbers of employees work in small enterprises and trade businesses.

Higher quality, lower costs

Even in times of increasing digitalization and Industry 4.0, good production performance by industrial and manufacturing companies depends to a great extent on employees' motivation levels. In this context, having the right light is becoming more important than ever. After all, well-planned industrial lighting (including intelligent lighting control and modern LED technology) makes a major contribution to companies' economic success. Modern lighting systems offer

- ***High efficiency:*** Up to 80 % lower energy costs and considerable savings in maintenance;
- ***Greater productivity:*** Correct lighting raises visual performance, promotes concentration, prevents fatigue and stress, maintains health, and protects against accidents at work;
- ***Greater flexibility:*** Well-planned lighting and systems that can be expanded without great effort will simply adapt to new work requirements;
- ***High degree of reliability:*** Professional planning, high-quality components, a reliable lighting management system and long-life LED luminaires increase operational safety.

However, even a cursory glance at numerous workshops and medium-sized companies reveals just how outdated many lighting systems still are. They consume too much energy, in many cases they no longer comply with the latest standards, and often only provide employees with poor workplace lighting – with corresponding consequences.

Putting people first

From small woodworking companies, laboratories and warehouses through to automotive engineering: the requirements for industrial lighting are as complex as the work tasks and the operating environments. Work processes are becoming increasingly complex and the lighting needs to accommodate a wide variety of visual tasks.

Standards define minimum values. More light is allowed – and in many cases is desirable. Numerous studies show that the number of work accidents decreases significantly with increasing illuminance.

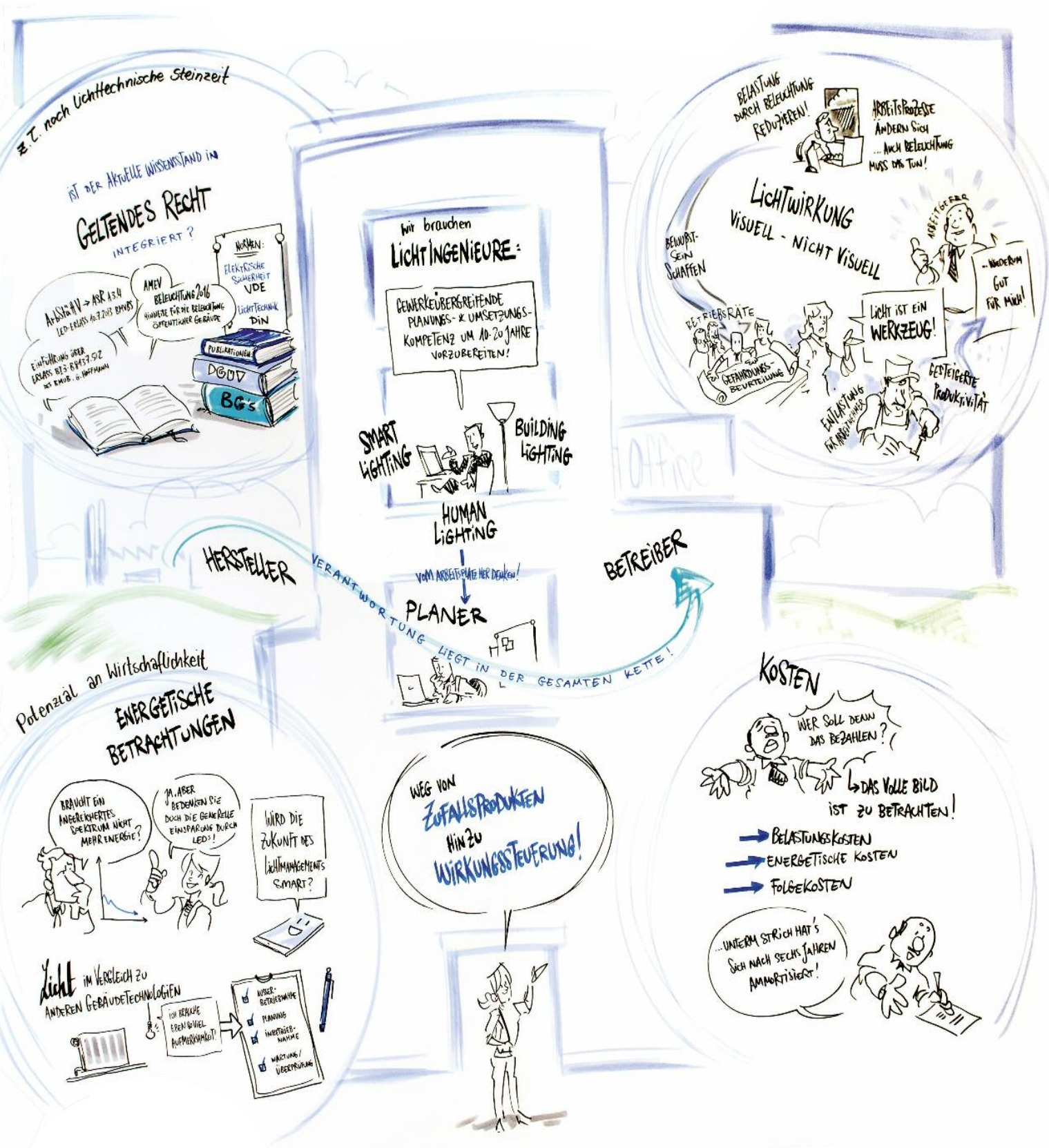
DIN EN 12464-1 "Lighting of indoor workplaces" states that visual comfort and visual performance are important lighting objectives. Good visual performance allows visual tasks to be performed even under difficult conditions and over a longer period of time. Modern lighting technology can do more: it offers solutions that reduce costs and at the same time guarantee high lighting quality for the people using it. It includes energy-efficient LED light sources, optimized luminaire systems and high-performance lighting management that controls lighting on the basis of presence and daylight. Such systems enable, for example, individual adjustments to be made which provide more light for older employees. At the same time, they offer greater flexibility because the lighting can be adapted more easily if work processes are changed.

People's visual, emotional and biological needs in the workplace, both during the day and at night, should always be at the heart of any lighting design. Human Centric Lighting supports the health and performance of employees, ensures greater production safety – and increases production quality.

In short: Better light for better work.

[02] Light for Industry and Trade. Many factors and requirements must be taken into account when planning a lighting system. Close cooperation between all those involved – professional lighting planners, operators, users and manufacturers – leads to tailor-made solutions for the individual lighting tasks.

Workplace lighting: The factors and players



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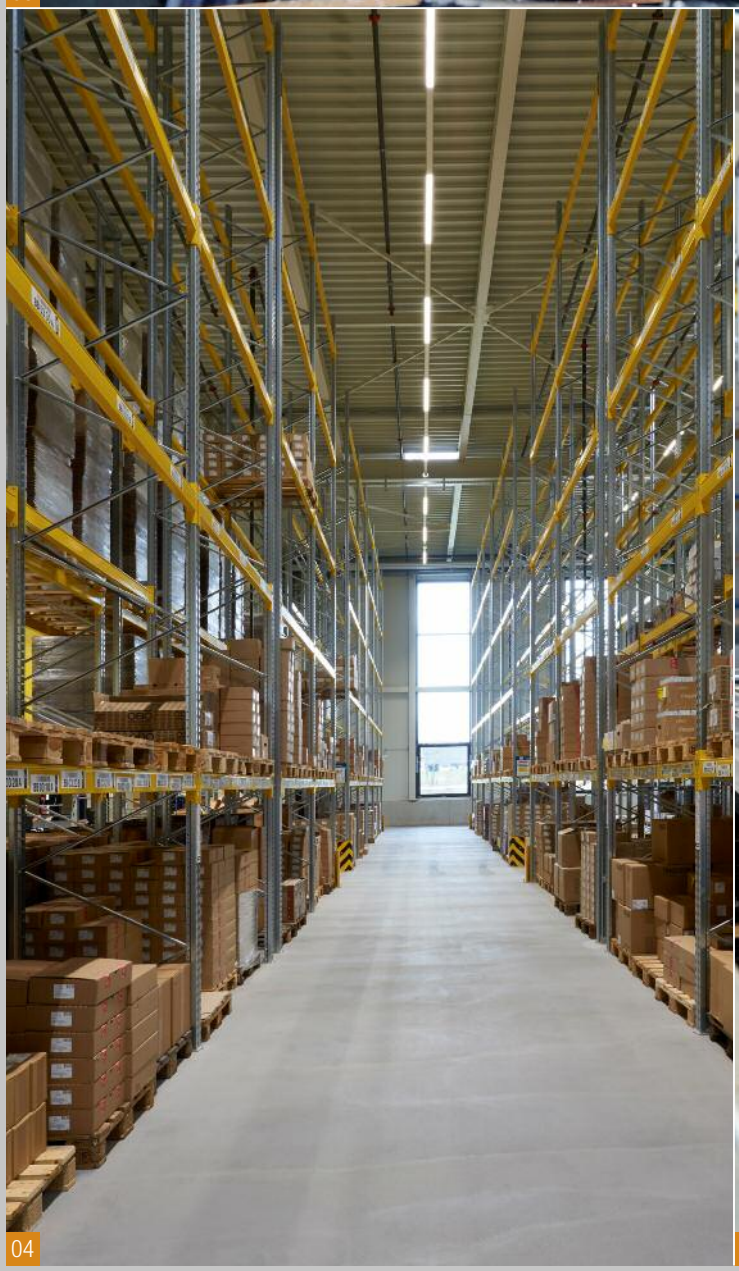

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Light and industrial safety

Correct workplace lighting is a decisive factor in ensuring the health and safety of employees. Company owners are duty-bound to ensure that lighting systems in trade and industry comply with the relevant standards and regulations as a minimum.

Good workplace lighting is an important prerequisite for preventing accidents. After all, occupational safety is ultimately also health protection. The World Health Organization defines health not only as the absence of clinical disease, but also as including mental and spiritual integrity and general well-being. Occupational safety thus goes far beyond accident prevention.

There are binding lighting requirements for workplaces throughout Europe. According to the Individual EU Directive for the Workplace (89/654/EEC),

- workplaces should receive as much daylight as possible and be equipped with appropriate artificial lighting for ensuring the health and safety of workers;
- the lighting of the working areas and connecting paths must be mounted so that the type of lighting does not pose an accident hazard to employees;
- sufficient safety lighting must be provided in workplaces where employees are exposed to significant hazards if artificial lighting fails.

Standards and regulations

In Germany, this EU Directive was implemented in the Workplace Ordinance (ArbStättV), which was last updated in 2016. In conjunction with the Occupational Health and Safety Act (articles 3 and 5), it obliges employers to equip workplaces in such a way to avoid any damage to employees' health. The general lighting requirements of the ArbStättV are further specified in the Technical Regulations for Workplaces ASR A3.4 – "Lighting".

> **"Workplaces should receive as much daylight as possible and be equipped with appropriate artificial lighting for ensuring the health and safety of employees"**
>
> *Workplace Ordinance (ArbStättV, Annex 3.4)*

When planning lighting, observation of ASR 3.4 (as a recognized technical regulation) is recommended in addition to DIN EN 12464-1 in order to meet all health and safety requirements. Lighting systems should therefore be planned, installed and maintained by appropriately qualified staff.

DIN EN 12464-1 and ASR 3.4 specify minimum requirements. Compliance with these does not necessarily result in optimum lighting for certain visual tasks. For example, more light is advisable for certain activities and also for older employees.

Quality characteristics of lighting

In general, a workplace is considered well-lit if:

- all working areas, communicating routes and break rooms are adequately illuminated,
- illuminance levels of 500 to 1,500 lux can be achieved in work areas with special visual tasks (e.g. very fine assembly work, quality control, office work), depending on the type of activity,
- the brightness is evenly distributed in the rooms, i.e. the ceiling and walls are as bright as possible,
- irritating glare and shadows are avoided,
- light sources with a suitable light colour and good colour rendering are used
- and they are flicker-free.

The output of existing lighting systems changes over time, meaning that companies should perform regular risk assessments to check whether the requirements of ASR A3.4 are still being met.

[03] The blend of daylight and artificial light at this industrial workplace ensures effective performance of the required visual tasks.

[04] Daylight should also be available in storage areas, if possible.

[05] Effective lighting makes a significant contribution to a company's success. Good lighting facilitates visual tasks, prevents fatigue, maintains health and protects against work accidents.

Further information can be found in the licht.de "Guide to DIN EN 12464-1" and DGUV Information 215-210: "Natural and artificial workplace lighting" and DGUV information 215-211: "Fit and healthy in small businesses: daylight in the workplace – performance-enhancing and healthy."

Light quality

Humans take in more than 80 per cent of information through their eyes. By implication, therefore, work can be hindered by poor visual conditions. They diminish the sense of well-being, reduce productivity, and cause mistakes and accidents.

The ability to perform visual tasks without strain determines the ergonomic quality of workplaces in trade and industry. Good lighting has a positive impact on work performance, error rates and accident prevention: those who can see well and feel comfortable in a pleasant ambience are more motivated, work with greater concentration and thus deliver a higher level of performance. The quality of work increases, the number of errors decreases measurably. The risk of accidents is also reduced. Lighting therefore also has a long-term health-promoting effect.

Customized solutions for industry
The visual requirements of industrial workplaces are very different to those in offices, for example. Sometimes the best solutions for the employees are not the same as those for the work processes. The yellow light used in greenhouses is good for plant growth, for example, but not for humans.

There are therefore no universally applicable solutions for industrial lighting; the lighting planning must be tailored to the individual room and the respective work processes. Nowadays, obtaining good lighting quality also involves supporting employees by providing good light for monotonous work processes, in areas with little or no daylight and in shift operation, and also by creating ideal visual conditions for the increasing number of older employees (*see also page 12*). Lighting systems which are capable of being modified and extended are flexible and can meet new requirements.

DIN EN 12464-1 lighting requirements
DIN EN 12464 Part 1 specifies requirements for “Lighting of indoor workplaces”. This key lighting standard specifies minimum values for all lighting characteristics. Overall, the quality characteristics help create ergonomic lighting in which disturbances, such as glare, are minimized. It is not sufficient to design a lighting system based around just one characteristic, such as illuminance.

Human Centric Lighting (HCL)
Light always has a multifaceted impact – visually, emotionally and biologically. Human Centric Lighting (HCL) supports people’s health, well-being and performance in a targeted and long-term manner through holistic planning and by exploiting the visual, emotional and biological effects of light.

Visual effect of light
The level and uniformity of light (resulting from different illuminance levels in the room) and the quality of glare limitation have a decisive influence on how precisely and how quickly visual tasks can be performed.

Emotional effect of light
Visual comfort is obtained by creating a harmonious distribution of brightness on vertical and horizontal surfaces, good colour rendering properties of the light sources and luminaires, and good glare control. Visual comfort generates a sense of well-being and thus contributes to an increase in performance. Light direction, shading and the light colour of the light sources determine the effect of the light in the room. This light climate, often described as visual ambience, essentially dictates how the atmosphere is experienced.


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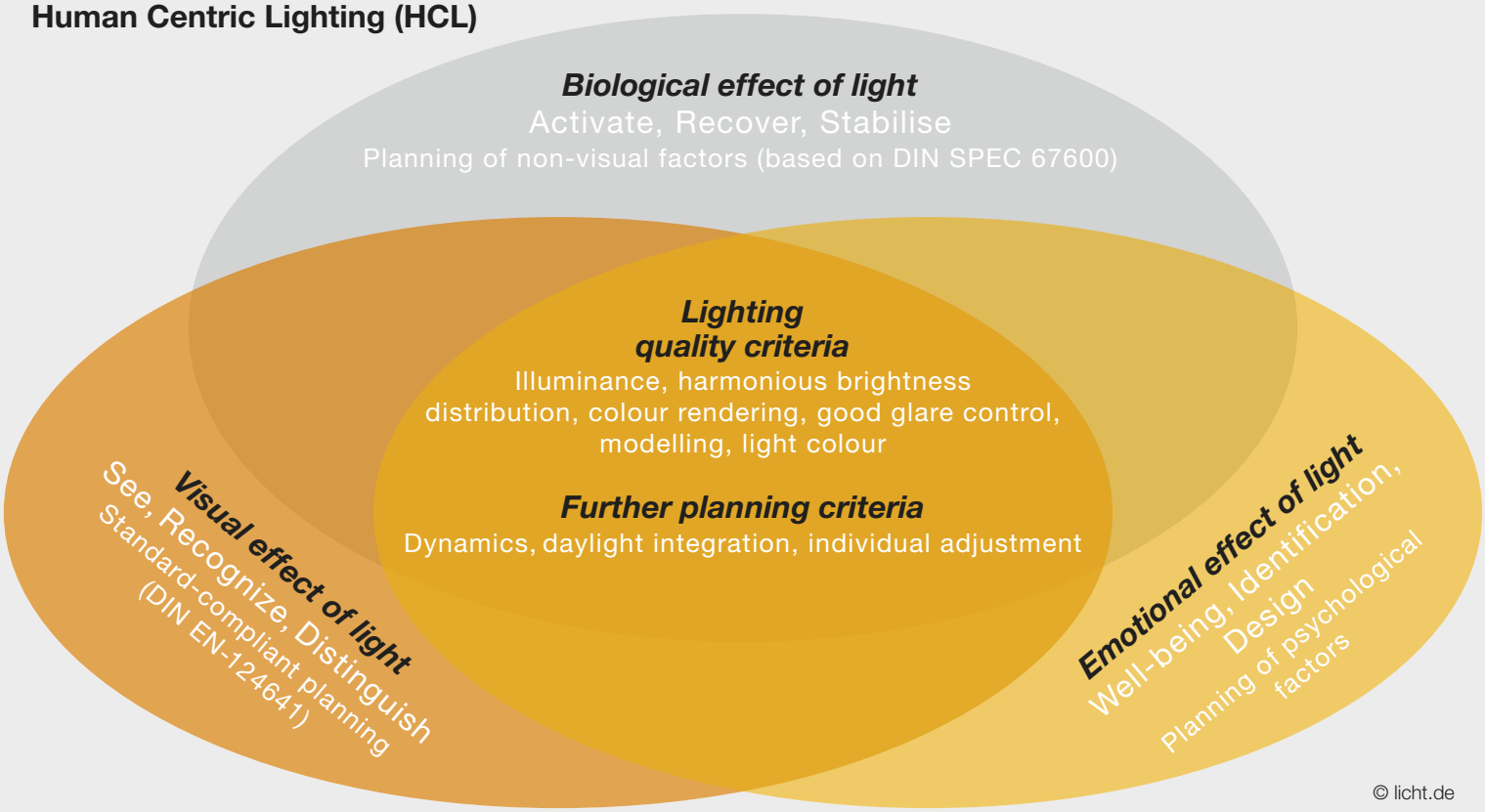
Biological effect of light
Each kind of lighting has a biological effect on the human body. The best reference is always natural daylight with its rhythm, spectrum and intensity. But electric lighting also influences our body clock, sleep-wake rhythms and many other functions. Applied deliberately and correctly, biologically effective lighting based on dynamically changing luminous intensity and different light colours can demonstrably increase motivation in the workplace.

Lighting quality characteristics
An optimum lighting solution which is geared to the people using it can be obtained if lighting quality characteristics and other planning criteria are taken into account during the design of the lighting systems. Important quality characteristics of good lighting are:
- Illuminance
- Harmonious distribution of brightness
- Good glare suppression
- Modelling (direction of light and shadows)
- Light colour and
- Colour rendering

Further planning criteria are:
- Dynamics
- Daylight integration and
- Individual adjustability

Quality characteristic: Illuminance
Illuminance (symbol: E) plays a particularly significant role in determining how quickly, reliably and easily a visual task is grasped and performed. Measured in lux (lx), it indicates the amount of luminous flux from a light source which falls on a given surface. Illuminance is measured on horizontal and



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vertical surfaces. Having a uniform distribution of brightness aids the performance of visual tasks.

The average illuminances specified in the standards are maintained values, i.e. the values below which average illuminance should never fall. If they are reached, maintenance work must be carried out *(see page 15)*.

Brightness or luminance distribution
Luminance (symbol: L) is the brightness of an illuminated or luminous surface as perceived by the human eye and is measured in candelas per unit area (cd/m²). Luminance impacts on visual performance and visual comfort. Higher luminance makes for greater visual acuity, better contrast sensitivity and thus enhanced visual function.

The luminance of surfaces is determined by their reflectance and the illuminance incident on them. This is why a white room with a given illuminance seems brighter than one with dark decor and furnishings.

Visual comfort is impaired by
- low luminance and excessive luminance uniformity, which make for a monotonous and unappealing lighting atmosphere
- excessive differences in luminance, which cause eye fatigue as a result of the constant need to re-adapt
- excessive punctual luminance which can cause glare.

Glare limitation
Glare may be direct – caused by luminaires or other excessively luminous surfaces, including windows (direct glare). Or it may be indirect, caused by reflections on shiny surfaces (reflected glare). Both direct and reflected glare reduce visual comfort (discomfort glare) and impair visual performance (disability glare).

Direct glare can be reduced if the surfaces of luminaires have the lowest possible luminance at flat angles, and direct view of the light source(s) is shielded. Direct glare is assessed using the UGR (Unified Glare Rating) method; standards define minimum values for glare protection. Reflected glare is prevented by ensuring that light is appropriately directed, surfaces in the room are matt and luminaire luminance is restricted.

Modelling and shadows
The luminous intensity, direction of light and shadows must harmonize to ensure that faces and objects can be recognized and perceived in three dimensions. A room with only indirect light and no shadows appears monotonous, while extremely directional light from point sources of light creates stark shadows that make vision difficult. Such stark shadows are a source of danger when handling tools or machines. Good modelling therefore requires a balanced mix of diffuse and directional light.

[07] Human Centric Lighting: Lighting that takes visual, emotional and biological quality characteristics into account contributes to health and motivates employees.

Light colour

The light colour of a lamp or luminaire indicates the intrinsic colour of the light that it radiates. This is determined on the basis of the most similar colour temperature (T_{cp}) in kelvins (K):

warm white (ww) < 3,300 K
neutral white (nw) 3,300 K to 5,300 K
daylight white (dw) > 5,300 K.

Warm white light is found to be homely and comfortable, neutral white light creates a more business-like atmosphere. Daylight white light is most similar to natural daylight and should only be used (from a biological point of view) at times when daylight is also available outside. In industrial applications with demanding visual tasks, light colours with a temperature of around 5,000 kelvins are often selected.

Colour rendering

The colour rendering property of a lamp determines the effect which its light has on the appearance of coloured objects. It is rated using the colour rendering index R_a. It indicates how naturally it reproduces colours. R_a = 100 is the best value. The lower the index, the poorer the colour rendering properties. Indoors, the value should not fall below R_a = 80. In areas with special requirements, e.g. for colour testing, colour rendering indices > 90 are suitable.

Integrating daylight

Daylight enables vision and provides a rhythm for the "body clock". DIN EN 12464-1 emphasizes the importance of daylight in workplaces, e.g. through windows, skylights and light-guiding systems.

Dynamics: the right light at the right time.

Recent scientific studies show that the timing and adaptation to individual users of lighting represent significant factors in addition to the classic quality characteristics.

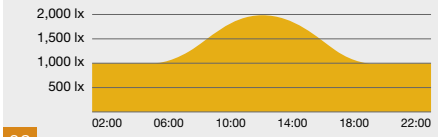
Of course, higher illuminance levels can always be installed while ensuring that all other quality characteristics are maintained. These may be changed dynamically depending on the work task at hand and the time of day. Targeted activation through the use of higher colour temperatures and illuminance levels is always useful and beneficial to health if synchronized with the time of day. At night, warm-white light colours and the lowest possible illuminance levels are recommended in the standards.

There are scientifically proven positive effects for users if the visual, emotional and biological quality characteristics of lighting are deployed dynamically and sustainably:

- greater motivation,
- greater drive,
- lower error rates,
- less fatigue,
- fewer occupational accidents,
- fewer absences.

Industrial lighting including non-visual effects can be implemented in accordance with DIN SPEC 67600. A distinction is made between two variants. If alternating day and night shifts are operated in a company, circadian lighting should help stabilize the normal day-night rhythm: the illuminance and blue components in the light increase continuously until midday and then decrease slowly towards evening; at night no daylight-white light should be used.

Circadian lighting in industry



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So-called "light panels" can also be used for stimulation during the day. In this case, the illuminance and light colour of the light is adjusted every hour, for instance. Light panels provide a greater sense of well-being, e.g. during monotonous work processes.

More light for older people

The eye lens becomes cloudy with increasing age, while the pupil width increases and the visual acuity decreases. 60-year-old employees need approximately twice as much illuminance as their 20-year-old colleagues in order to have the same impression of brightness. More light than "normal" is required from the age of 35. These requirements are best met with individually switchable light. Alternatively, the overall lighting level in the room can be adjusted to the lighting requirements of a 60-year-old, for example; younger people then dim the light.

Adaptation of illuminance to the work task

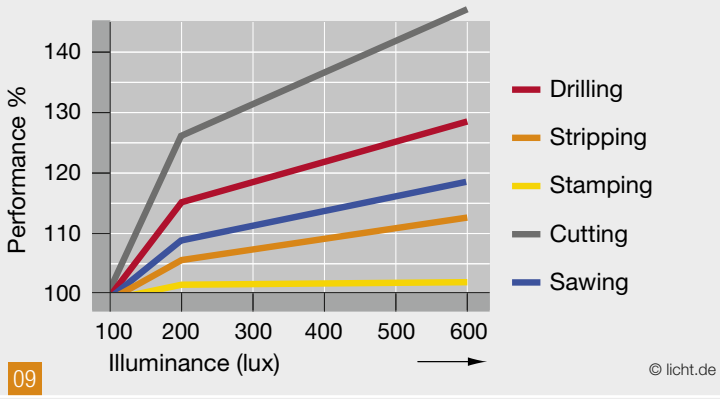
Workplaces must be illuminated with higher illuminance levels for tasks which are more complex or carry an increased accident risk. The correlation between illuminance and employee motivation has been measured in various long-term studies at industrial workplaces. These revealed that the increase in performance in difficult visual tasks when the illuminance is increased was significantly greater than in simple visual tasks. At the same time, the error rate dropped. Long-term studies also showed that higher illuminance led to less fatigue. This is not only relevant in terms of reserve capacity, but also with regard to accident prevention.

Further information on the subject can be found in licht.wissen 19 "Impact of Light on Human Beings" and in licht.wissen 21 "Human Centric Lighting Guide".

At higher illuminance levels
[09] ... performance increases,
[10] ... the error rate drops,
[11] ... employees are more alert.
These figures come from scientific studies carried out at the TU Illmenau:
"Nutzen einer besseren Beleuchtung", 1998, Gall, Völker.

[12 –14] Older employees need more light than their younger colleagues. Good glare-free workplace luminaires provide additional light.

Light increases work performance



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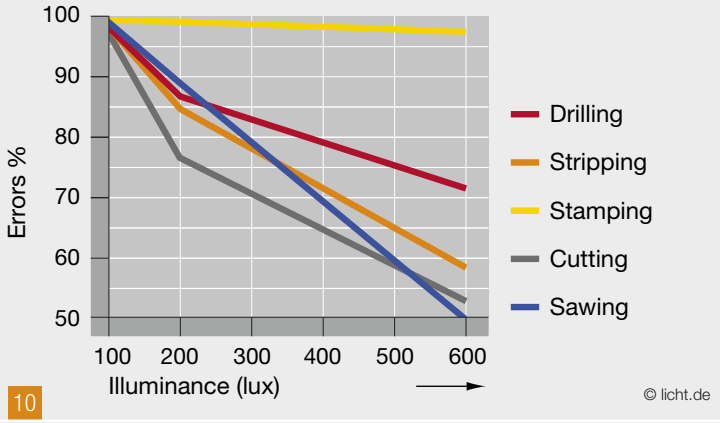
Light reduces error rates



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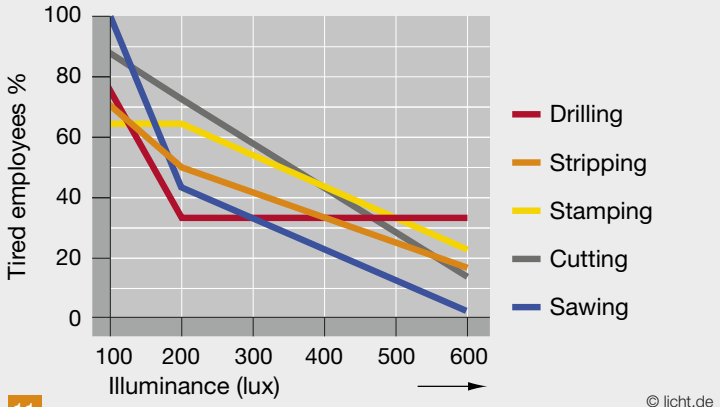
Light prevents fatigue



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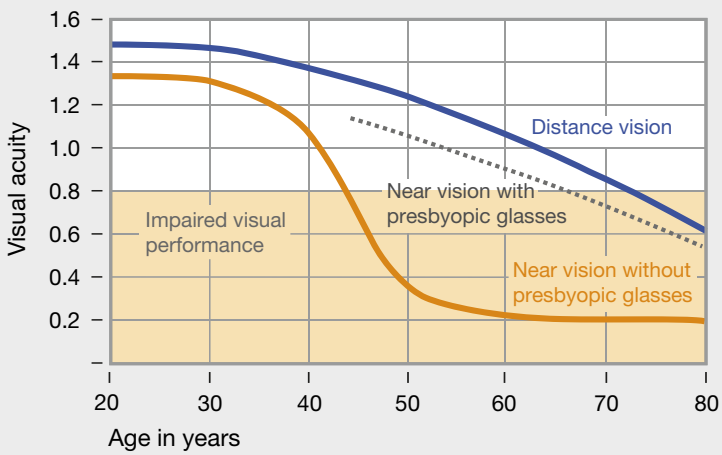
Visual acuity and age



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Light planning

The right lighting is a prerequisite for good vision and ensures a pleasant lighting climate. Expert planning is required in order to meet the diverse requirements of ergonomically and photometrically perfect lighting.

The planning of a lighting system ensures that the lighting creates good working conditions upon being turned on, and which are then maintained over a long period of time. Planners should ensure that their specifications are adhered to in the installation and operation of the lighting. Ideally, they should also dictate what happens to the lighting equipment at the end of its life. Recycling and environment-friendly disposal increase the sustainability of the solution.

Indoors it is crucial is that all visual tasks – especially at work places – can be completed satisfactorily and that any irritation, e.g. in the form of glare, is avoided where possible. New lighting concepts should be based on the specific lighting demands and focus on the individual visual tasks. The quantity and quality of the lighting can then be precisely determined for each area of the work place.

Compliance with accepted technical regulations, such as the German work place regulation ASR A3 4 and the DIN EN 12464-1 standard, is recommended during the planning stage. The standard defines the lighting for the area of the visual task, the activity, or the room. Achieving a balanced mix of required brightness levels for all work areas is the best option. There are three basic lighting design concepts:

- ***Room-based lighting*** – provides uniform lighting throughout the room and is the preferred option if the arrangement of the work places has not been decided or should remain flexible.
- ***Activity-based lighting*** – focused on an area in which a number of different visual tasks are to be performed.
- ***Visual task-based lighting*** – is usually focused on specific individual areas. One such typical area would be the work top of a desk.

Room-based lighting

If the precise arrangement of workplaces is not known at the time when a lighting installation is planned, DIN EN 12464-1 stipulates that the areas of the room where workplaces could be located should be illuminated in the same way as the visual task area. The advantage of such room-based lighting is that the workplaces in this area of the room can be re-arranged at any time.

Visual task area

The quality characteristics of DIN EN 12464-1 are not intended per se for the entire room; they apply above all to the visual task area – i.e. the part of the workplace in which the visual task is performed. In industrial workplaces, visual tasks can be both horizontal and vertical (e.g. on machines). The standard allows lower values for the immediate surrounding area, i.e. the area that is within the field of vision of the person working. However, the values must not be lower than those given in section 4.3.2 of the standard.

Concentration of the lighting on the visual task area can reduce investment and energy costs, but it carries risks with regard to the quality of lighting. This is always the case, for example, when the visual task area and the (less well illuminated) surrounding area are so narrow that the luminance distribution in the field of vision is not even. The visual task areas must therefore be carefully defined.

Immediate surrounding area

A workplace can consist of several visual task areas, including those with different visual and lighting requirements. Each visual task area is assigned a corresponding immediate surrounding area with lower lighting requirements. In its “Guide to DIN EN 12464-1”, licht.de recommends combining the visual task areas into a single work area with an immediate surrounding area in such cases. If the position of the workstations is not known, this work area can also be the entire room.

The standard stipulates a width of at least 0.5 m for the immediate surrounding area.

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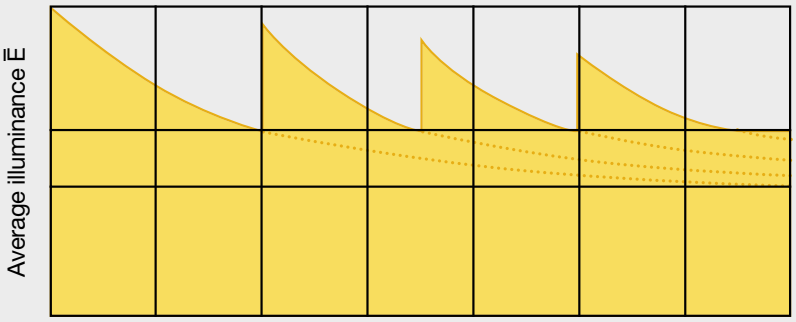
Maintenance cycles



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Here the lighting requirements are lower. Nevertheless, the luminance distribution in the employee's field of vision must not be adversely affected. Therefore, the average luminance in the surrounding area must be at least one third of the luminance of the visual task area: the more the better. The immediate surrounding area must be widened, if necessary.

Work areas and sub-sections
Alternatively, the lighting can be based around individual work areas. Where separate lighting is provided for the individual visual tasks, the light is directed onto these sub-sections.

Maintenance and maintenance factor
The luminous flux of a lighting system decreases over the operating life, as light sources, luminaires and room surfaces age and accumulate dirt. For this reason, the average illuminances specified in the standard are maintained values, i.e. the values below which the average illuminance should not fall. Higher values are planned for new lighting systems in order to sustain the maintained value over a longer period of time. These higher values are determined based on the maintenance factor. The following is used for planning: maintained illuminance = maintenance factor x illuminance on installation.

The maintenance factor depends on the type of light source and luminaire, the level of dust and dirt in the room or environment as well as the maintenance method and schedule. In many cases the exact effect of operation on the decline in illuminance is not known at the time of planning the lighting. In such cases a maintenance interval of three years results in a maintenance factor of 0.67 (in clean rooms), rising to 0.5 (in rooms subject to high levels of dirt).

LED luminaires are designed for a long service life. The LED modules are not planned to be replaced in many cases. The maintenance plan must therefore include both: the permanent loss of luminous flux and regular cleaning of the luminaires.

The planner must document the maintenance schedule for a lighting system. This documentation can be created with appropriate lighting design software and included in the maintenance manual. The operator of the system is responsible for adhering to the maintenance plan.

Use of luminaires with a higher IP rating
Luminaires with a low degree of protection – for example IP 20 – attract dirt faster than closed luminaires with a higher rating of IP 50 or more. Accordingly, they must therefore be serviced earlier, and sealed luminaires later. The table below shows a comparison of the luminaire maintenance factors.

Professional planning
Complex lighting tasks require specialist expertise. Qualified professional planners know what is currently state-of-the-art and the relevant regulations.

It is also important that all parties work together from the outset on an interdisciplinary basis. The lighting concept should always be based on an analysis of the property:

- Which activities and visual tasks need to be carried out where?
- What are the users' and investors' needs?
- What architectural, furniture or machinery requirements need to be taken into consideration?

Only when the lighting concept has been drawn up can suitable light sources and luminaires (plus corresponding lighting management systems) be selected.

licht.wissen booklet 01 "Lighting with Artificial Light" provides further information on lighting design.

Comparison of luminaire maintenance factors (LMF)

Cleaning frequency	1 year				2 years				3 years			
Environment	VC	C	N	D	VC	C	N	D	VC	C	N	D
IP 50 luminaire	0.96	0.94	0.90	0.86	0.93	0.91	0.86	0.81	0.92	0.90	0.84	0.79
IP 20 luminaire	0.94	0.88	0.82	0.77	0.91	0.83	0.77	0.71	0.89	0.79	0.73	0.65

VC=very clean/C=clean (clean rooms, data centres)/N=normal (assembly bays, warehouses, laboratories)/D=dirty (chemical plants, woodworking)

[15] Multiple visual task areas on a lathe that are combined to form a single work place area (light and medium yellow). The strip of the surrounding area is at least 0.5 metres (dark yellow).

[16] The maintained value is the value below which the lighting systems must not fall during the operating time of the system.

High efficiency lighting solutions

Low energy consumption is one of the required characteristics of a lighting system nowadays. Efficient lighting technology and the intelligent use of daylight protect the environment, reduce operating costs and contribute to business success. A lighting management system makes sense here.

DIN EN 12464-1 stipulates the importance of making "no compromises at the expense of technical lighting quality characteristics ... merely to reduce energy consumption" (section 4.9), calling for artificial light to be produced with the lowest possible energy consumption. The European Union, which sets rules for the energy performance of buildings in directives such as the 2010/31/EU EPBD (Energy Performance of Buildings Directive), places a clear emphasis on saving energy. These regulations include energy efficiency, environmentally friendly design and lighting technology in buildings.

Energy certificates also for small businesses

The energy performance certificate is based on Directive 2002/91/EC – implemented in Germany as the Energy Saving Ordinance (EnEV) – and has been mandatory for non-residential buildings since 2007: it assesses the total energy requirements of a building, including lighting. Heavily frequented buildings and usable areas of more than 500 square metres have been included since the last major amendment in 2014. This means that even smaller companies generally require an EnEV certificate in accordance with DIN V 18599.

Building owners are obliged by the EnEV to determine the total energy consumption of a building: before the refurbishment or new construction of a building, the primary energy consumption for lighting must be calculated as defined in DIN V 18599, Part 4, and approved before the start of the construction work.

Components of efficient lighting

Lighting has become considerably more efficient with the use of LEDs – the quality of light has also increased correspondingly. Other efficient lighting components include:

- High quality luminaires with high operating efficiency and optimized light guiding,
- Long-life electronic control gear and ballast units with low failure rates
- Lighting concepts with multiple switching groups which can be dimmed and controlled individually and independently of each other
- Lighting management systems which include daylight and room occupancy.

Using luminaires with a higher IP rating than is actually necessary also saves energy: a lower initial illuminance value (new value) can be selected for the maintained value (*see page 15*) because they remain clean for longer.

Lighting management as reference technology

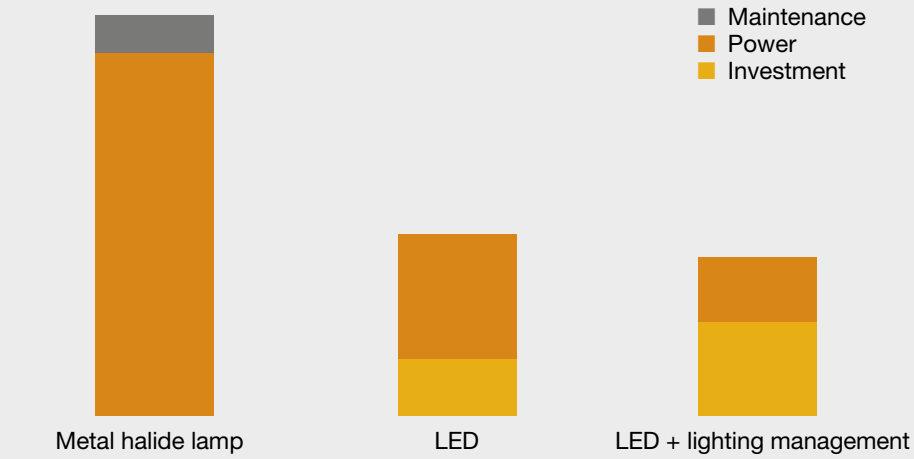
Only with electronic control systems can operators take advantage of all the benefits offered by modern light sources, luminaires and control gear units. A new lighting system with daylight and presence control yields up to 80 per cent savings in comparison to the energy costs of an old system.

Areas of buildings that are not in constant use offer high savings potential; in industrial facilities, for example, these include warehouses, traffic routes, changing rooms and sanitary facilities. A lighting management system allows lighting to be switched on/off and controlled based on presence. Lighting can also be electronically dimmed and controlled in areas receiving a large amount of daylight without compromising comfort.

The Government has recognized this – and has declared the use of lighting management systems in such areas as a reference technology in EnEV 2014. This means that electronic lighting control is required as a minimum standard.

Those involved in lighting planning are not always aware of this. Planners should bear in mind that issue of the energy performance certificate is generally conditional upon the use of the reference technology. In many buildings, lighting management systems are therefore mandatory in order to meet the EnEV requirements (*cf. p. 55*).

Sample analysis of lighting costs of an industrial building* over 10 years



* Industrial building 30 x 50 m / 300 lux illuminance / 3,000 operating hours per year.

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[17] Savings through modern technology: Investment in a new lighting system quickly pays for itself – through better lighting quality.

[18] Sensors in the luminaires regulate the lighting based on the daylight rhythm.

[19] Switching to energy-efficient light sources in combination with lighting management systems saves electricity and operating costs.

Reference technology of lighting management for exemplary applications (EnEV 2014)

Usage profile Non-residential buildings	Lighting management		
	Constant light power control	Presence detector	Daylight-dependent control
Single office	X	–	X
Group office (two to six work places	X	–	X
Open-plan office (seven or more work places)	X	–	X
Meetings, conferences, seminars	X	X	X
Circulation areas	–	X	–

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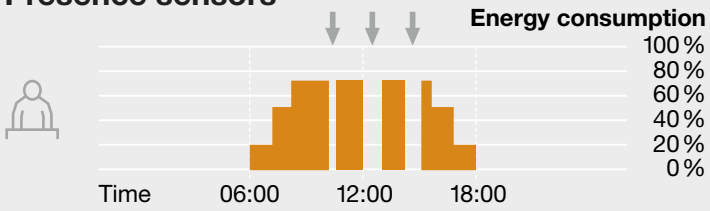
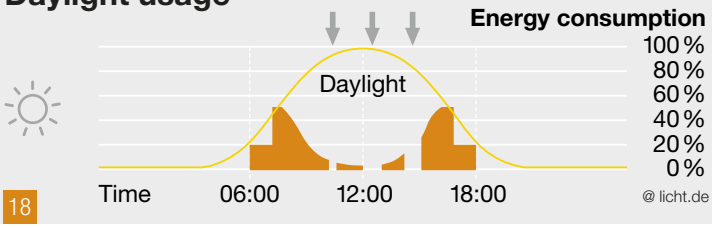
Presence sensors



Daylight usage



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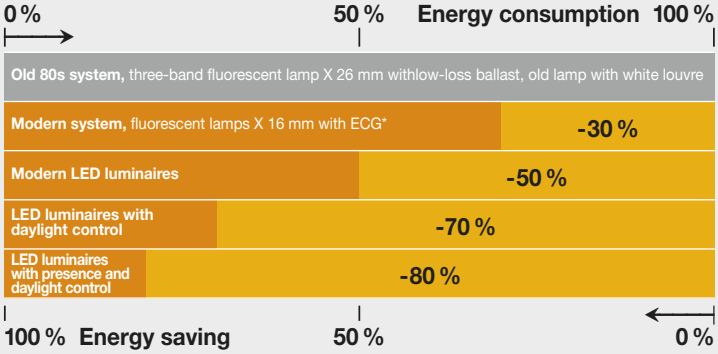
Potential savings in interior lighting



Example based on 2-unit spacing office

* Fluorescent lamps with low power dissipation, luminaires with modern light guiding

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Systematic modernization

A structured modernization process helps to identify potential efficiency increases and ensures high lighting quality at low electricity costs over the long term. There are five steps to achieving this goal.

The lighting equipment in many companies is obsolete. Such systems

- consume too much energy,
- drive up electricity costs
- require a high level of cleaning and maintenance
- often no longer comply with current standards and
- in many cases only provide poor light quality.

This makes work more difficult, leads to high error rates and reduces performance.

Over the years, the operating efficiency of an old system and the associated components – lamps, luminaires and control gear – can be halved due to dirt and material ageing. Almost 90 per cent of the costs of a lighting system today are accounted for by the operating costs, energy consumption and maintenance work. Consequently, investment in ergonomic and efficient lighting usually pays for itself within a few years. The older the system to be replaced and the longer it is operated each day, the higher the savings.

Best form of modernization: "new" for "old"

As a rule, the best solution is to replace an old system completely with a professionally planned new system including lighting management system. Just as with a new building, experts should be involved right from the start in the modernization of a lighting system. This applies in particular if the client's initial intention is only to replace individual components for cost reasons. Caution is required here, because the VDE marks on luminaires may lose their validity if control gear or light sources are changed. If such cases, the operator of the system is liable for its safety.

Changing reflectors is also critical, unless they are explicitly provided by the manufacturer of the existing system.

Professional modernization planning

Careful analysis and professional planning are the basis of all lighting modernization. The aim is to draw up a comprehensive modernization roadmap that contains the profitability calculations for individual lighting projects. The optimum modernization strategy can then be selected based on the data and the resulting calculations.

It is also easier to decide which projects should be brought forward for economic reasons. This allows modernization to be carried out gradually in sections over several years. In this case, the modernization begins either in the rooms or parts of buildings with the longest operating time or starts with luminaire and lamp types that offer the highest savings potential.

Step 1: As-is analysis

Those who define precise goals at the beginning will find it easier to achieve savings and improve the lighting quality later on. 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
- Lighting calculations and assessment of the existing systems
- Benchmarks with comparable lighting systems. In the simplest case, the power consumption of the lighting system is correlated with the illuminated area (i.e. Watt/m² per 100 lux per year).

Step 2: Planning

When planning lighting, the visual tasks must be defined, numerous standards and directives must be observed and lighting quality features must be taken into account. The actual planning takes place in five steps:

- Definition of the lighting concept and choice of lighting types

As-is analysis | Planning | Financing | Installation | Maintenance & inspection

- Selection of suitable luminaires and components
- Calculation of the required number of luminaires and their arrangement
- Definition (where applicable) of lighting management and
- Definition of the maintenance schedule.

Planning also includes a cost-effectiveness calculation that covers various lighting options – lamp and/or luminaire replacement – and compares different luminaire solutions.

Step 3: Financing
Often only limited financial resources are available for the modernization of lighting systems. Appropriate financing concepts can therefore represent a good way of changing to energy-efficient lighting – ideally without any extra burden on the budget. Assistance is available through:

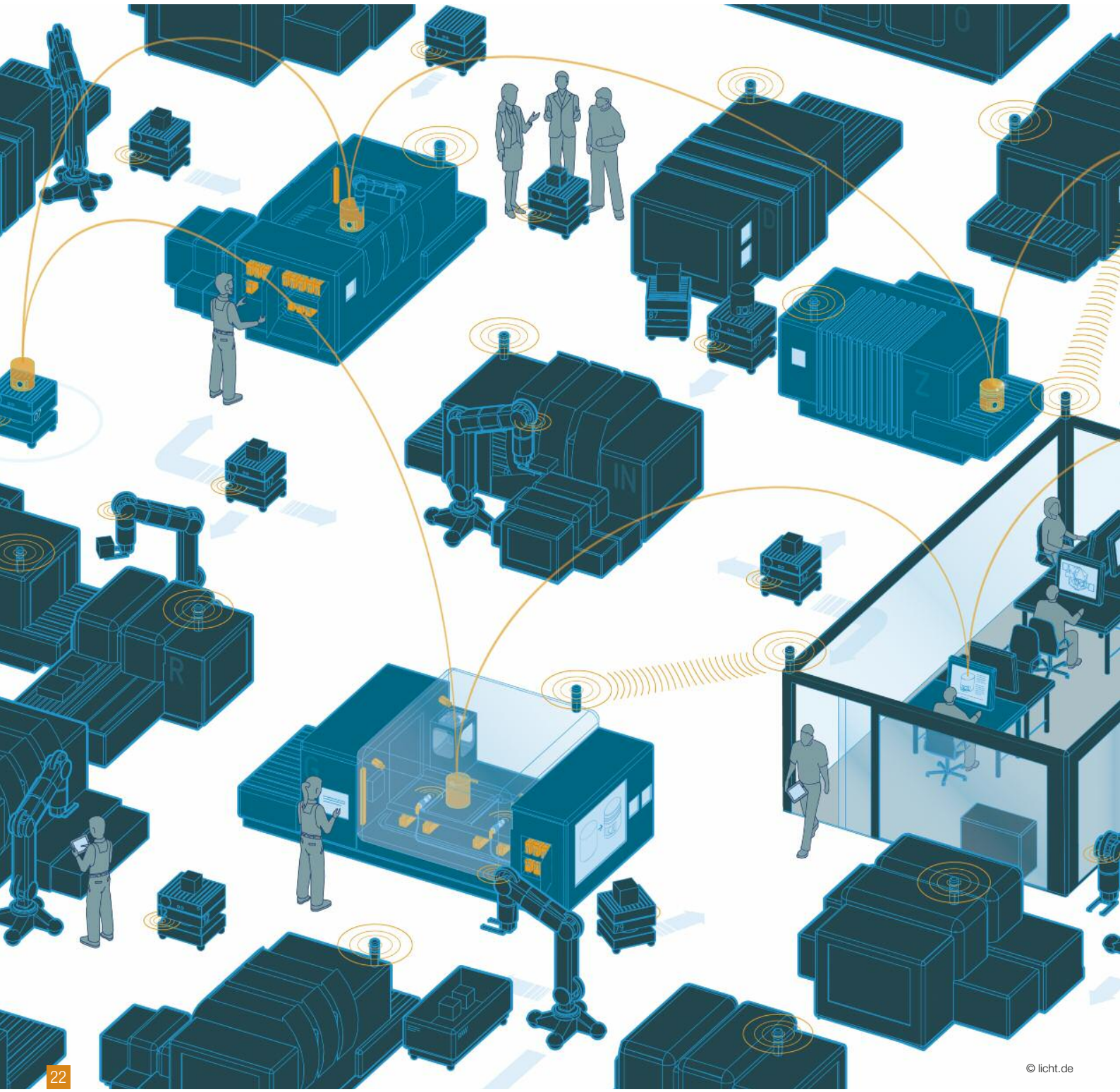
- Contracting: Here, a service provider invests in efficient lighting and assumes the economic risk.
- Financial support: The Federal Government and the government-owned KfW Bank support the modernization of old lighting systems in numerous programmes.

Step 4: Installation and initial operation
Professionally planned lighting systems also require professional installation. This ensures that all components – luminaires, light sources, operating devices and presence/daylight measurement sensors – are optimally adjusted, and that the planning objectives for light quality and energy savings are met. Poorly adjusted systems often do not deliver the desired performance.

Step 5: Maintenance and inspection
DIN EN 12464-1 stipulates the generation of a maintenance plan as a mandatory part of the lighting design. Optimum maintenance increases the service life and efficiency of a lighting system. In addition, the maintenance of lighting systems can provide valuable information and key pointers for future projects.

Further tips and practical examples can be found in licht.wissen 09 “Refurbishment in Trade, Commerce and Administration”.

[20 + 21] Better light quality, greater efficiency: A modern lighting system including lighting management ensures a pleasant atmosphere and agreeable working conditions, even in production facilities.



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[22] Digitalization is changing the world of work. In smart, networked factories, machines are taking over more and more routine tasks, controlled by sensors and microprocessors.

Smart buildings, smart lighting

Digital information structures are heralding the fourth industrial revolution in the world of work. The increasing interlinking of machines and data is changing manufacturing and logistics processes while opening up new opportunities for companies. The lighting system plays an active role in this in smart buildings: it collects usage data, reacts flexibly to changes and provides each workplace with the optimum lighting quality.

Is demand-oriented lighting and Industry 4.0 a contradiction in terms? Not at all. In the age of Industry 4.0, people's needs are of great importance and the topic of "Human Centric Lighting" (HCL) is gaining in significance.

Putting people first

The requirements of various fields of work can be met through the flexible adjustment of modern lighting systems, from the assembly plant to the logistics centre, allowing the lighting of production layouts to be changed quickly and easily. The modern world or work, in which flexible working conditions are now of great importance, benefits from smart lighting: innovative sensor technology permits the use of lighting that can automatically adapt to presence, users and activities and take into account the visual, emotional and biological needs of people working in the day and at night.

In Germany, one in six people work shifts (Federal Ministry of Labour, 2016) and must regularly change from daytime to night-time working. Studies have shown that lighting solutions with dynamically controlled illuminance and colour temperatures can support this change. Added to this are increasingly complex, non-automatable activities involving correspondingly demanding visual tasks, and demographic changes: older employees need more light than their younger colleagues. Both benefit from good lighting quality that motivates and supports error-free working.

Light is dynamic and networked

Demand-based lighting offers not only health benefits for employees, but also potential for economic savings. The Fraunhofer Institute has developed an Industry 4.0 workplace concept: here, modern lighting adapts to the increasing demands of companies based on the activities involved and ergonomic aspects. Dynamic adjustment options for light colour, intensity and guiding during the different work stages, as well as the digital interconnection of machines and systems support the assembly of a product at all times. A workplace with activity-based lighting thus increases the productivity of employees while simultaneously reducing errors and improving overall working conditions.

Early response through big data analyses

The efficiency of an entire building can be increased by interconnecting luminaire sensors. Digital lighting control collects lighting and presence data on the movement sequences and times of people and resources, on whether an activity is energy-intensive or low-energy, on machine usage times, and it enables remote access.

This data is used to facilitate decision-making regarding servicing or new investment as well as for adjusting temperature, lighting and cleaning schedules during intensive or low-level use. This, too, can help improve working conditions and yield economic savings.

Demand-based lighting and corresponding lighting management systems can support the revolution in the world of work through situational optimization, integrated networking, intelligent lighting systems for buildings and new solutions for shaping the working environment.

Ambient conditions

From clean rooms to waste incineration plants: there are as many different ambient conditions in industry as there are applications. The materials, nature and construction of the lighting equipment should reflect this.

Functioning lighting is a basic safety requirement in any industrial operation. However, the ambient conditions in the various industrial applications differ considerably. Before deciding on a lighting system, it is therefore advisable to check the ambient conditions and to assess which properties, construction aspects and materials need to be taken into consideration for luminaire housings, seals and enclosures.

Foreign object protection

In many applications, particles are introduced into the air during production. Smooth, easy to clean and particle-repellent surfaces are recommended. The first code number of the IP rating according to DIN EN 60598-1 indicates the maximum size of particles which can penetrate into the luminaire.

Moisture protection

The second code number of the IP rating indicates the moisture protection level of the luminaire. A high degree of luminaire protection must be ensured for applications involving water baths, steam or frequent cleaning with water (steam cleaners).

Chemical protection

There are no materials which are resistant to all types of influence. The list of chemicals and their influences is wide-ranging and can fill volumes of resistance tables. All potential hazards should therefore always be carefully assessed. Materials such as polymethyl methacrylate (PMMA) or polyamide (PA) should be selected in aggressive environments. In metalworking environments where greases and oils are used, for example, care must be taken to ensure that no relevant components of the lighting systems are made of polycarbonate (PC), as this can be damaged.

Fire protection

Dust and shavings can settle on luminaires, causing high surface temperatures and fire hazards. The D marking specifies the surface temperatures on luminaires designed for fire-hazard locations.

Safety lighting

Safety lighting which is compliant with DIN EN 60598-2-22 must meet special criteria. For example, in the event of a fire, such safety lighting must be powered externally from a central battery system or diesel generator, or alternatively luminaires with integrated rechargeable batteries must be used. Furthermore, such lighting must be designed to offer sufficient resistance to high ambient temperatures, and certain components must be subjected to a “glow wire test”.

Explosion protection

Explosion-protected luminaires must be used in numerous industrial fields: in large chemical plants, on oil platforms or in refineries, but also in grain mills, silos or sawmills. The risk of combustion must be actively prevented by using explosion-protected (Ex) luminaires.

A total of 13 possible combustion sources have been identified. Electrostatic and electromagnetic sources are regarded as possible causes of unintended ignition, in addition to thermal or electrical ignition sources. It is important that the luminaire’s protection features extend beyond the housing: internal components such as cable glands must also be considered.

Decisive for classification of the luminaire are the ignition protection type (the method of active prevention of ignition sources) but also the temperature class and the gas group. Both of these determine the permitted and possible use of the luminaire.

Table Degrees of protection

	1st figure protection against foreign bodies and contact	2nd figure protection against water
0	non-protected	non-protected
1	protected against solid foreign bodies> 50 mm	protected against dripping water
2	protected against solid foreign bodies> 12 mm	protected against dripping water when 15° tilted
3	protected against solid foreign bodies> 2.5 mm	protected against spraywater
4	protected against solid foreign bodies> 1 mm	protected against spraywater
5	protected against dust	protected against jets of water
6	dustproof	protected against heavy swell
7	–	protected against temporary immersion
8	–	protected against prolonged immersion
9	–	Protection against water during high pressure jet/steam cleaning

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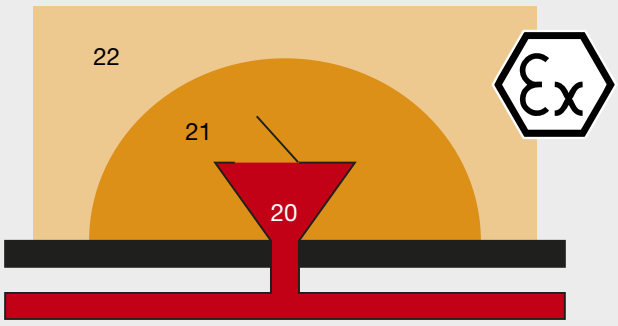
Group	Dust	Dust hazard
IIIA	Flammable fluff	+
IIIB	Non-conducting dust	++
IIIC	Conducting dust	+++

Group	Test gas	Gas hazard
IIA	Propane	+
IIB	Ethylene	++
IIC	Hydrogen	+++

Tempera-ture class	Combustion temperature of gas	Max. surface tempera-ture of equipment
T1	> 450°C	450°C
T2	> 300°C ≤ 450°C	300°C
T3	> 200°C ≤ 300°C	200°C
T4	> 135°C ≤ 200°C	135°C
T5	> 100°C ≤ 135°C	100°C
T6	> 85°C ≤ 100°C	85°C



Zone 20: Hopper of a bag emptying station – the greatest explosion hazard is in zone 20
Zone 21: Immediate vicinity (radius 1 m) around the open loading hatch
Zone 22: Area outside zone 21 due to dust deposits

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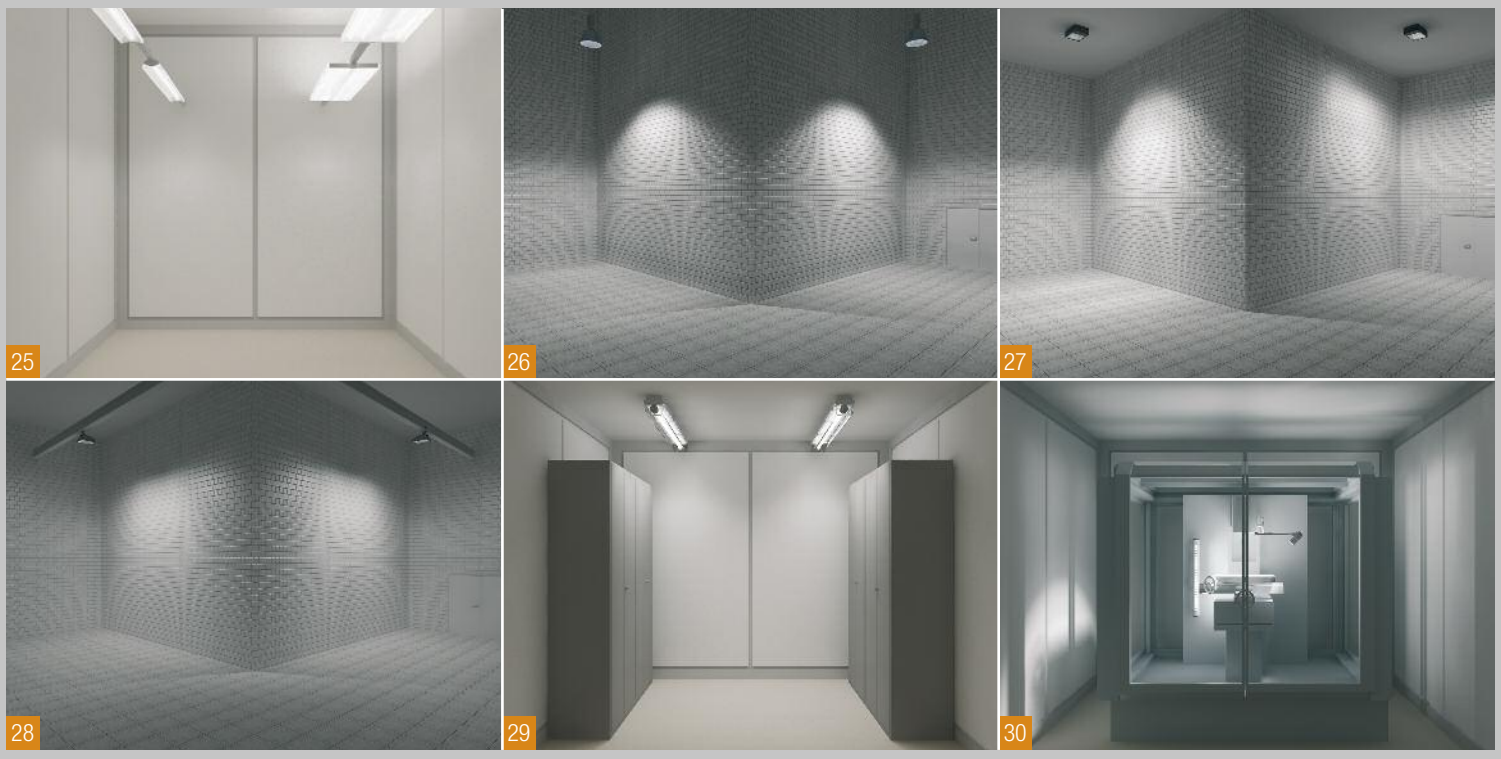
[23] Many types of gas and dust are flammable and explosive. Explosion-protected luminaires and equipment must be used in hazardous areas.

[24] Example of zoning by degree of danger, here for particulate flammable substances, into zones 20, 21, 22. Zones 0, 1 and 2 are defined for gas, mist and vapours.



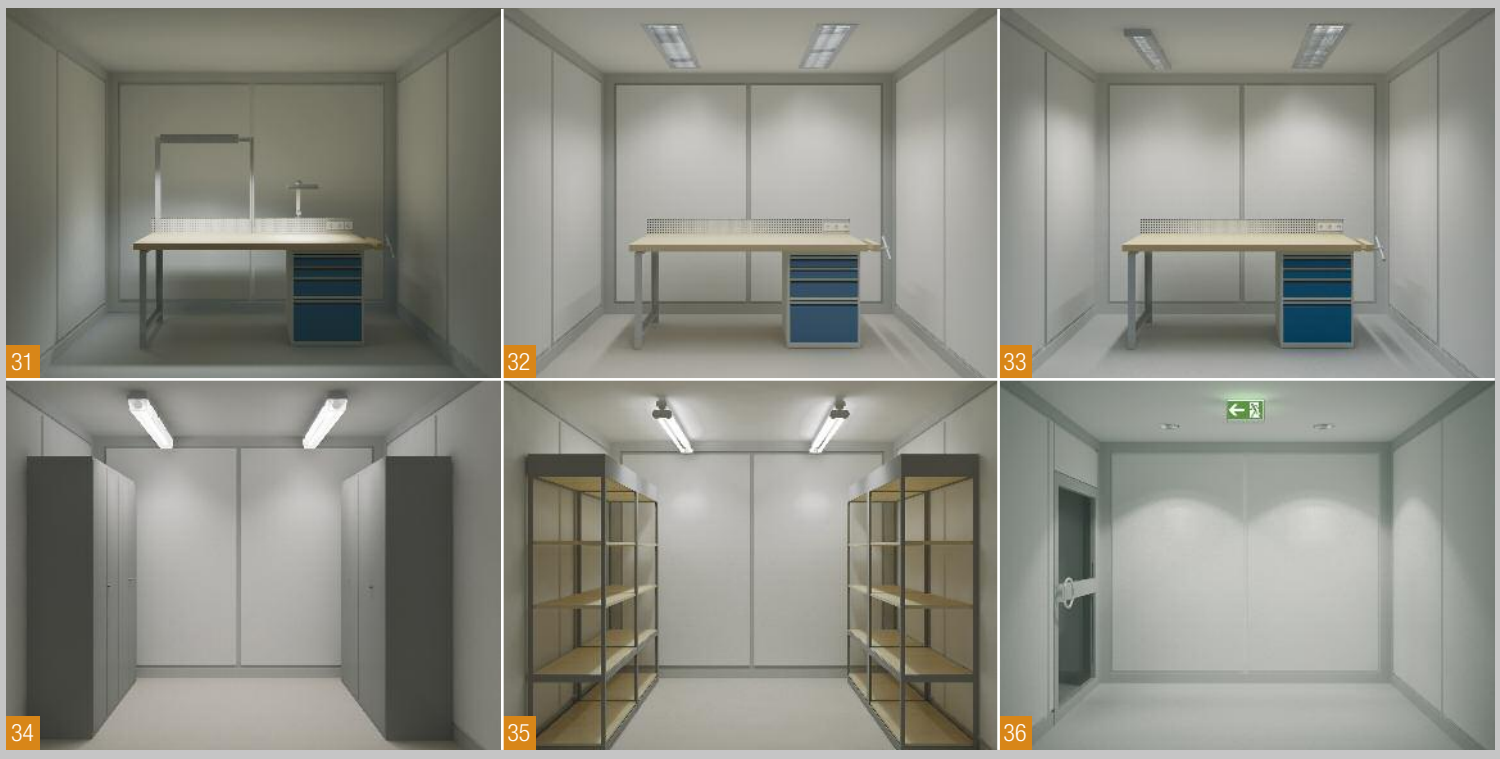
Luminaires

Luminaires distribute and direct the luminous flux of one or more light sources. A luminaire includes all components for mounting, operating and protecting the light source.

Luminaires are divided into two main groups: illuminating luminaires and luminous luminaires. While luminous luminaires should create a direct effect in the eyes of the observer – e. g. signalling, advertising or aesthetic glare –, illuminating luminaires brighten the surfaces that the human eye is looking at, perceiving and/or assessing.

A further subdivision of this group of luminaires defines specific properties of the luminaires, such as IP protection, IK protection or the chemical compatibility of the materials used. All industrial luminaires are also divided into interior and exterior luminaires. Further characteristics that play a part in the decision of which luminaire type to install are:

- Luminaire efficiency: only efficient luminaires help to save operating costs;
- Light quality: Light sources and optical systems with optimum illumination of work surfaces are appropriate for industrial facilities;
- Electrical quality: Approval (e.g. ENEC, VDE), power factor, inrush current, inter-



play between mains quality/luminaire (Total Harmonic Distortion, THD);
- Service life: both the light source and other electronic components in the luminaire determine the maintenance cycles;
- Product ergonomics: ease of installation, ease of maintenance, aesthetics;
- Type: the operator decides whether to use panels, point light sources or recessed luminaires.

There is also the group of hand-held (= portable) luminaires. Special requirements apply here too.

[25] Luminaires in continuous strip lighting system for direct (left) and direct/indirect light distribution (right), IP 20 rating

[26] High-bay reflector luminaire with axially symmetrical light distribution, IP 65 rating

[27] High-bay reflector luminaire with symmetrical (left) and asymmetrical (right) light distribution

[28] Floodlight with asymmetrical light distribution for large industrial areas, IP 65 rating

[29] Explosion-proof luminaire (Ex luminaire)

[30] Machine luminaire in conventional tubular machine luminaire (left) and LED machine luminaire (right) versions, IP 67 rating

[31] Workplace luminaire as system (left) and universal (right) luminaire, IP 20 rating

[32] Cleanroom luminaire, IP 65 rating

[33] Louvre luminaires for ceiling (left) and recessed mounting (right), IP 20 rating

[34] Moisture-proof diffuser luminaire, IP 65 rating

[35] Batten luminaire without reflector, IP 65 rating (moisture-proof luminaire)

[36] Escape sign luminaire, IP 23 or IP 65 rating for industrial bays

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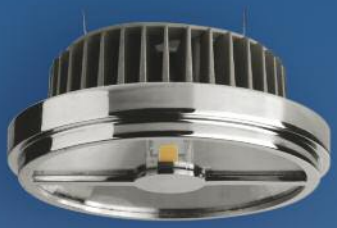

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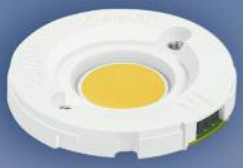

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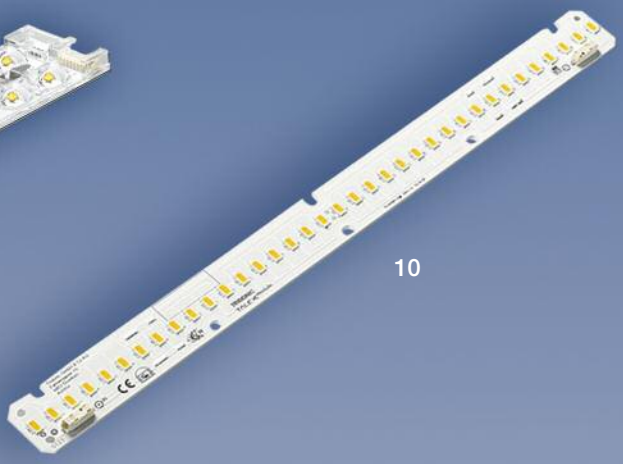

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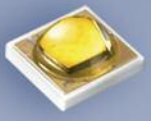

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LED light sources

LED light sources are available in a wide variety of designs – from ready-to-use retrofit solutions to flexible LED strips and LED modules that meet even the most exacting demands. The LED portfolio includes perfect solutions for even the most challenging of special designs.

[37] Overview of common LED retrofit lamps, LED strips, LED modules and LED packages. A suitable LED solution now exists for every application.

Conversion

If a luminaire is converted to permit it to accept e.g. a tubular LED lamp, this is referred to as a conversion (or refit). This requires technical changes to the luminaire design. As a rule, the starter and the control gear must be replaced and the internal wiring exchanged or modified. The lighting properties of the luminaire always change, too, as the LED replacement has different radiation characteristics e.g. to a fluorescent lamp. The following points must be observed:

- Luminaires should only be converted by an authorized specialist company.
- The conversion causes the luminaire to lose its approval and, where applicable, the manufacturer's warranty.
- The conversion creates a new product which requires a new conformity assessment. This is the responsibility of the party modifying or placing the luminaire on the market, and who thus becomes the luminaire manufacturer.
- The conversion company carries responsibility for product liability and warranty.
- The converted luminaire must be given a new type plate.
- Lighting properties should be checked and, if necessary, adjusted to the legally prescribed values.

LED retrofit lamps
The quickest and easiest introduction to LED technology is to fit a suitable LED retrofit lamp into an existing luminaire. The luminaire (including socket) remains unchanged, but is updated using efficient technology and a structurally identical LED retrofit lamp. LED lamps are available in many versions. They are characterized by their high energy efficiency and good colour rendering. Depending on the system, they can also be dimmed, colour-controlled, or integrated into a network using smart technology. NB: Electrical and photometric compatibility must be ensured when LED retrofit lamps are used in luminaires. Three main types are available on the market:

[1] Substitutes for tubular fluorescent lamps (T8, T5)
Tube-shaped LED lamps require significantly less energy than conventional fluorescent lamps. They do not flicker when switched on and provide full luminosity immediately. Note: Conversion, see grey panel on the left.

[2-3] Substitute for radiating light sources, single or double-ended
LED lamps replace conventional incandescent and halogen lamps in the classic "bulb" shape and with E14 or E27 screw bases. Lamps with different plug-in bases, single or double-ended bases, can also be replaced with little effort.

[4-5] Substitute for reflector lamps
Conventional reflector lamps can also easily be replaced by LED retrofit lamps. Here the market offers a large selection, including different light colours and beam angles.

Flexible LED strips [6-7]
Flexible LED strips are particularly suitable for decorative lighting. However, ever higher luminous fluxes are also rendering them attractive propositions for room lighting, for example in coves. In this case, it is imperative to ensure good heat dissipation.

LED modules [8-11]
LED modules consist of PCBs fitted with individual LEDs. Depending on the configuration, these light sources can also be equipped with light guiding optics and a heat sink. Technical safety, reliability and performance requirements are described in Regulation 1194/2012/EU and the safety and performance standards DIN EN 62031 and DIN EN 62717. As a rule, ballast units are required to operate an LED module.

Basis: The LED
The above LED light sources consist of the following LED components:

[12] Low and mid-power LEDs with electrical outputs of 0.1 to 0.5 W are used. They consist of a simple plastic housing with a lead frame for heat dissipation and power supply, and a chip.

13] High-power LEDs with an electrical power of 1 to 5W are often used in floodlights and street lighting. Precise light guiding is achieved using special plastic optics.

[14] Multi-chip LEDs are constructed using highly integrated chips behind a larger conversion surface, e.g. COB (chip-on-board). They are used, for example, in downlights or hall and table luminaires.

Quality requirements of LED luminaires

Efficient LED light sources also offer optimum solutions in modern industrial lighting. There are many different LED products on the market – but not all of them fulfil their promise. So what are the key aspects?

High-quality LED systems must meet certain criteria. These include:

- high luminous efficacy of the entire system
- light colour and homogenous brightness, including the ability to retrofit older models to yield the same light quality
- good heat dissipation and
- long service life with as few premature failures as possible.

The luminaire data sheets of the manufacturers provide information on the rated values, e.g. luminaire luminous efficacy or light colour.

Luminous efficacy of LED luminaires

The luminous efficacy is the measure of the efficiency of light sources and is given in lumens per watt (lm/W). In practice, however, it is not only the luminous efficacy of the light source that is decisive, but also the efficiency of the entire system comprising light source, luminaire housing, optics and control gear.

In the case of LEDs, unrealistically high light yields of more than 200 lumen/watt (lm/W) are frequently advertised. These, however, are “laboratory values” that have been produced under ideal conditions. They cannot be obtained in practical operation due to electrical, optical and especially thermal losses. When comparing luminaires, therefore, care should always be taken to ensure that the luminous flux emitted by the luminaire is considered, not that of the LED chips.

It should also be noted that the luminous efficacy of the luminaire is not a suitable basis for evaluating energy efficiency, as not all the light emitted actually falls upon the working plane. A photometric calculation must therefore always be made for the area under consideration.

Good heat dissipation

Whenever light is created, heat is also generated. It must be effectively dissipated to ensure that LED luminaires have a long service life and deliver maximum luminous flux. Therefore, good thermal management with suitably effective heat sinks in the luminaire housing must be considered right from the design stage. As a rule of thumb: the lower the temperature, the longer the service life of the LEDs and the more efficient and brighter their light.

Service life of LED systems

Depending on the operating conditions, LED systems can have very long service lives compared to traditional lighting technologies, and are virtually maintenance-free.

The service life of LED systems is usually indicated in hours. Experts call this the rated service life.

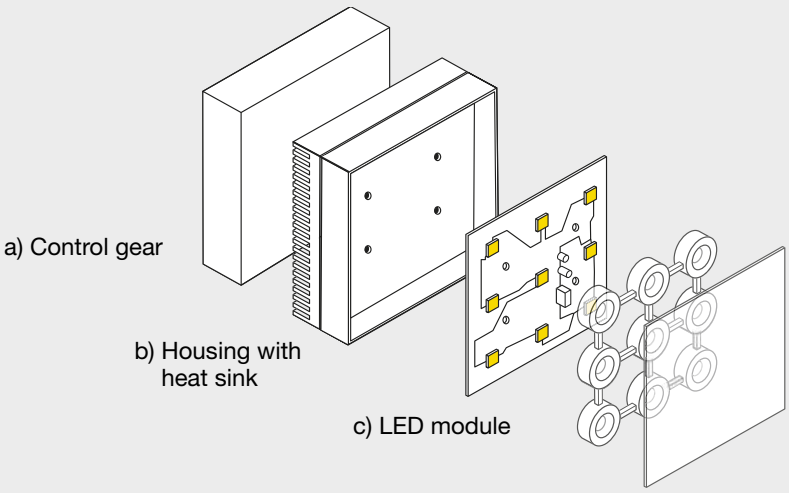
LED lights rarely fail completely, but their brightness decreases during operation. The rated service life (given as L_x) describes the time in which the luminous flux of the LED falls to the specified value. For general illumination, typical values are L_{80} or L_{70}. Thus the average rated service life is reached when the luminous flux reaches 70 per cent of its value at installation.

Degradation and the rare total failure of an LED depend largely on the current feed and heat dissipation; ambient and operating temperatures have a strong influence on the service life of the LED.

As with conventional technologies, the possible failure of LED drivers is not taken into account and the manufacturers must be asked specifically for this.

The ZVEI “Reliable planning with LED lighting” guide provides information on terminology, definitions and measurement procedures.

Sample LED luminaire structure



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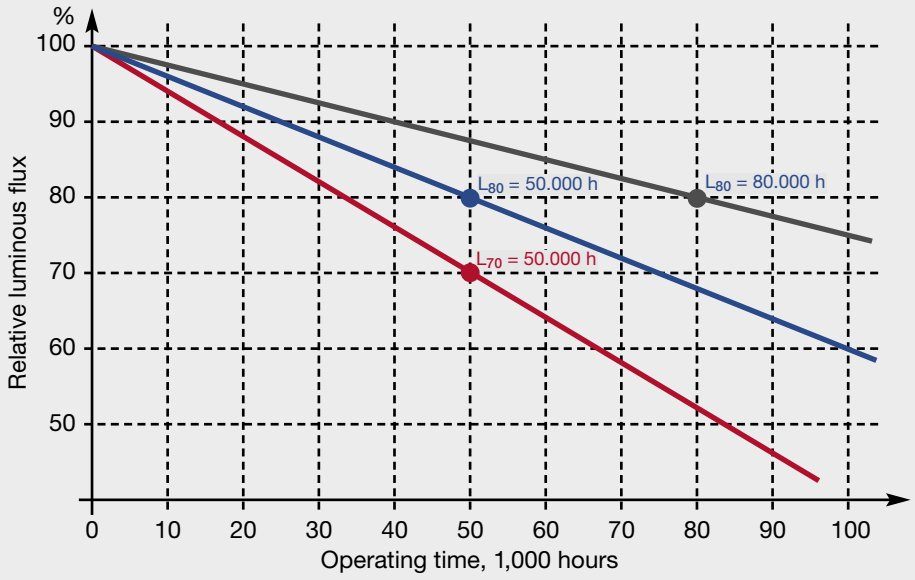
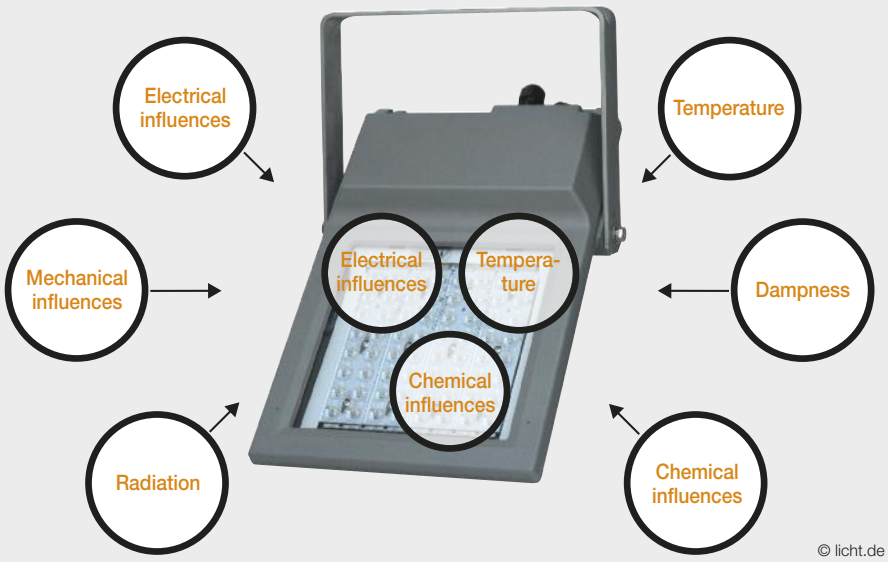
Graph showing light over service life



Simplified representation

39

Internal and external factors affecting LED service life



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[38] Sample LED luminaire structure: The heat generated on the LED board must be dissipated via a dedicated heat sink in the housing in order to maintain light quality and durability. The optics provide light control and a suitable beam angle.

[39] LED systems rarely fail. However, their light output decreases over time. The service life is given as L_x. Typical examples of the proportion x (as %) of the rated luminous flux are e.g. 70 or 80 per cent (= L_{70} or L_{80}) at a given rated service life of 50,000 hours and an ambient temperature of 25° C for the luminaire.

[40] High-quality LED systems with good thermal management are generally more-or-less maintenance-free throughout their service life. Nevertheless, many factors influence the service life.

Electrical engineering and electronics

Activities in the electrical trade and electrical industry are being strongly impacted by the digitalization process. Micro- and nanotechnology are becoming part of the value creation cycles. The classic products are increasingly assuming higher integration densities and being given forward-compatible electronic interfaces (Internet of Things, IoT). The visual tasks are very diverse.

[41 + 42] Disturbing stroboscopic effects can be avoided for machines or processes with continuous movements (e.g. rotation) if the luminaires are operated with electronic ballasts (EBs). It must also be ensured that only current-amplitude-dimmed ECGs or alternatively ECGs with a sufficiently high PWM frequency (≥ 2 kHz) are used with LED luminaires.

Light for the electrical trade
The activities in the electrical trade are characterized by the great variety of the tasks; there is a correspondingly wide range of visual tasks. It is advisable, therefore, to provide individual illumination for workplaces and their task areas. The average illuminance levels for such tasks range from 300 lux (lx) to 500 lx. Precision work requires up to 1,000 lx, testing and adjustment 1,500 lx.

Working on and with larger devices requires special lighting, as unwanted shadows can easily occur. Both vertical and horizontal illuminance must be taken into account. In this case, wide-angle or asymmetrical luminaires and luminaires that can be directed as required are the right choice.

Additional light should always be available for test and control stations and other activities with higher visual requirements.

Electronics workshops
Communication and consumer electronics workshops have similar requirements to those of the electrical trade. An average illuminance of at least 500 lx needs to be provided for the visual tasks associated with the growing proportion of integrated circuits and miniaturization. Additional workplace lighting is required when spatially complex or high-precision work is carried out on workpieces or circuits. This improves 3D vision and helps maintain concentration.

Electronics manufacturing
The lighting requirements for electronics

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production are comparable to those of the electrical trade. Electronic hardware is becoming ever smaller and its manufacture increasingly automated or performed by robots. Humans are performing more checking tasks and are less involved in the flow processes.

The small structures involved in PCB assembly – such as microprocessors – require high illuminance levels because these are often black and thus light-absorbing. The manufacturing processes require high air purity levels, i.e. it must be free of dust and microorganisms. Lighting is provided by clean room luminaires.

An average illuminance of 300 lx is sufficient for the production of components such as cables, wires or large coils, and for electroplating or assembly work. The lighting level must be raised to at least 750 lx for smaller production workpieces or the assembly of precision components.

Production and quality control monitor screens must be suitably illuminated. Care must be taken to avoid glare; disturbing reflections should be avoided.

Lighting systems
The illuminance levels of room lighting, workplace lighting and special workplaces must be balanced to ensure good vision. A luminance distribution ratio of 10:3 is recommended to avoid the need for excessive adaptation by the eyes. Bright walls, floors and ceilings (in the absence of skylights) are helpful.

The recent success of LED technology has made energy and resource management easier to implement. Integrated in a building management system, lighting systems with daylight control and presence detectors guarantee maximum economic savings in modern production facilities, and extend service lives.

Light strips attached to or suspended from the ceiling are suitable for mounting heights of between four and six metres, as are LED low bay or high bay luminaires. Light strips with narrow-beam optics can also be used in higher buildings.

Luminaires with higher IP ratings, e.g. IP 65 or IP 66, should be installed in order to extend maintenance periods and in the event of higher dust levels. In chemically contaminated areas, e.g. those used for pickling or electroplating, corrosion-resistant luminaires with a high IP rating (at least IP 65) and corresponding fixings must be used.

DIN EN 12464-1 requirements: Electrical industry

Room, task or activity	E_m	UGR_L	U_0	R_a
Cable and wire production	300	25	0.60	80
Winding, large coils ... medium coils ... small coils	300 500 750	25 22 19	0.60 0.60 0.70	80 80 80
Coil impregnating, electroplating	300	25	0.60	80
Assembly work, rough (e.g. large transformers) ... medium fine (e.g. switch panels) ... fine (e.g. IT products) ... precision (e.g. PCBs)	 300 500 750 1,000	 25 22 19 16	 0.60 0.60 0.70 0.70	 80 80 80 80
Electronics workshops, testing, adjusting	1,500	16	0.70	80


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Metalworking, plant and machinery

The visual task requirements vary along with the wide range of activities performed: the simple visual tasks include basic assembly and forging work, whereas welding and medium-fine machine work present higher demands. The eyes are challenged to the maximum during high-precision work on machines, for soldering and at control and measuring stations.

Basic assembly and open-die forging in metalworking
Basic assembly, drop forging and open-die forging are among the less sensitive visual tasks, for which 300 lux (lx) are sufficient; 200 lx mean illuminance is required for open-die forging. In high bays, industrial LED luminaires with appropriate optics provide economical lighting. However, they are unsuitable if shiny metal parts are frequently processed there because their light then produces strong reflected glare. In this case, linear LED luminaires with diffusers are more suitable.

Welding
An average illuminance of 300 lx is required at welding workplaces. Static or mobile workplace luminaires should also be used for supplementary lighting. The higher illuminance on the workpiece can compensate for the low light permeability of welding goggles.

Light for lathes and for soldering
Clamped workpieces must be illuminated from the operator side. The longitudinal axis of linear luminaires is arranged transversely to the lathe to avoid stark shadows. In addition, a well-shielded, adjustable work luminaire is required to provide the glancing light needed to make workpiece details more clearly discernible.

During soldering work it is particularly important to inspect the result. Luminaires with opal diffusers are best suited for lighting here.

Mechanical and plant engineering
The lighting for machine and plant construction is room or work area-based. The required illuminance varies between 300 and 500 lx. Bright vertical surfaces and higher illuminance levels in the visual task areas have a positive impact on health and productivity *(see page 10ff.)*.

Precision machining
An average illuminance level of 500 lux is required for precision work with tolerances < 0.1 millimetre. The metal parts being processed often have shiny and therefore reflective surfaces, which leads to reflected glare. Bright walls and a bright ceiling are therefore recommended to minimize reflected glare in cases where the lighting is based on lines of LED luminaires with diffusers.

For assembly lines, the visual task areas are best illuminated using parallel strip lights. Additional workplace luminaires are necessary here, as sufficient illuminance is often also required on inclined working planes.

Workstations with monitors
Lighting needs to be display-screen compatible at CNC machines with monitors. Only low-luminance luminaires – e.g. those with microprisms, or special computer workstation luminaires – can effectively prevent distracting reflections on the screen. Additional light from mobile luminaires is almost always required for setting up machine tools.

Precision engineering workshops
Tiny parts are processed, sorted or produced in precision and micro-engineering shops. Fine tolerances require particularly accurate measuring processes. Meeting the exacting visual requirements requires an

DIN EN 12464-1 requirements: Metalworking

Room, task or activity	E_m	UGR_L	U_0	R_a
Open die forging, plate machining (> 5 mm)	200	25	0.60	80
Sheet metalwork (< 5 mm)	300	22	0.60	80
Welding, drop forging, electroplating	300	25	0.60	80
Tool making, cutting equipment manufacture	750	19	0.70	80
Basic assembly work Precision assembly work	200 750	25 19	0.60 0.70	80 80
Surface refinement and paintwork	750	25	0.70	80

average illuminance of at least 1,000 lx. For delicate operations at least, supplementary workplace luminaires should be used.

Control and measuring stations
There must also be high average illuminance levels in places where inspection, measurement and testing is carried out: 750 lx to 1,000 lx. In addition, a balanced ratio of direct to indirect lighting is important to ensure that three-dimensional shapes can easily be recognized and distracting reflections avoided. Another important lighting criterion is good recognisability of the scales and screens of measuring instruments. Bright room surfaces – especially bright ceilings – are important in these areas, in addition to high-quality lighting.

Lighting systems
Linear and continuous light-strip luminaires are the favoured option for use in the metalworking and plant and machine construction sectors. As flexible systems, they can easily be adapted to accommodate changes in production processes.

Continuous LED light-strip systems with appropriate optics are suitable for both low and high bays. Alternatively, linear luminaires can be used for heights of up to six metres, and LED high bay floodlights at heights of six metres and more. Additional workplace luminaires are required for tasks with exacting visual requirements.

Enclosed luminaires with a higher IP rating (IP 54 or IP 65) should be installed in areas with high dust levels. In principle, a high degree of protection will extend the maintenance interval. In rooms requiring a high degree of cleanliness but which do not have to meet cleanroom requirements, the luminaires should be easy to clean and should not have surfaces on which dirt can accumulate.

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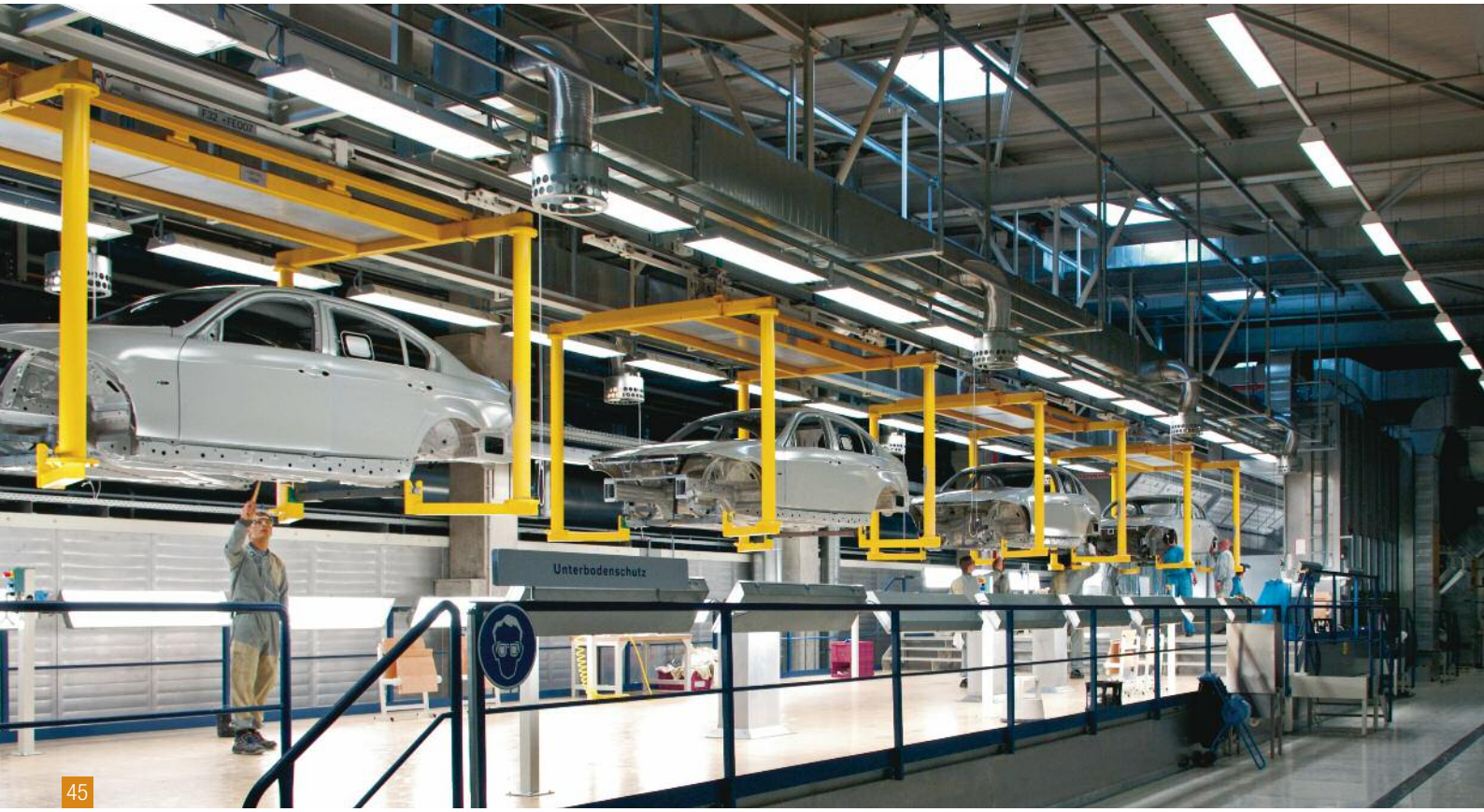
[43] Suspended LED pendant luminaires provide glare-free light at the workstations.

[44] Continuous LED light strip systems are suitable in halls up to six metres high



45

Automotive industry

The automotive industry is characterized by its extensive vertical range of manufacture. The production steps extend from heavy work, such as forming or welding, to precision assembly and visual inspections. The lighting requirements are correspondingly varied.

In the automotive industry, production and process workflows change rapidly. Modern lighting systems should therefore offer maximum flexibility which allows the lighting to be adapted quickly and efficiently. Individual work places are illuminated by means of room or work area-based lighting. Where necessary, workplace luminaires supplement this light with higher illuminance levels, e.g. when handling small parts.

Body construction and assembly
An average illuminance of 500 lux (lx) is generally regarded as the minimum for body construction and assembly. Most assembly work places are on the production line. Here, care should be taken to ensure that continuous light-strips mounted parallel to the line cause as little glare as possible and ensure a uniformly high lighting level. The required illuminance level must also be provided during installation work inside the vehicle. Workplace-specific lighting should be used for precision tasks, e.g. at individual workplaces.

Paint shops and spray booths
The paint shop and spray booths require average illuminance values of between 750 and 1,000 lux. It should also be noted that explosion-protected luminaires are often used in these applications (ATEX Directive 1999/92/EC). This also applies to areas where large amounts of dust are generated, such as during grinding work.

Upholstery and final inspection
1,000 lux average illuminance must be guaranteed in the upholstery and final inspection bays. Such high values can best be achieved in these areas using individual luminaires. Wide-panel inspection luminaires, for example, avoid reflected glare and other optical interference – especially with shiny parts.

Nowadays, many automobile manufacturers carry out quality tests of painted surfaces (or frequently also of the entire body) in light tunnels. The lighting systems are mounted in arches, can be individually controlled and allow even the smallest irregularities to be detected through the use of special lighting scenarios.

There are also special luminaires for colour matching. By changing the colour temperature, they enable the topcoat, for example, to be subjected to rigorous inspection and colour tone errors to be easily detected.

Large companies often have their own in-house standards. In some cases, these significantly exceed the industry standards. Before planning, the parameters should be checked so that they can be factored in accordingly.

Lighting systems

Low-maintenance LED downlights are recommended for production and logistics areas with ceilings of more than six metres in height. Higher IP protection (IP 54 and higher), heat resistance and resistance to possible emissions (e.g. oil vapours, welding fumes) should also be considered in challenging environments (pressing plant, body shop, etc.). LED continuous light-strips with moderate dust protection are recommended for ceiling heights of up to six metres. Luminaires with microprisms, or special computer workstation luminaires provide glare-free light in areas with displays and monitors.

Additional information: Substances which interfere with wetting agents (e.g. silicone) are now banned by many car manufacturers in all product areas – even in lighting systems.

[45 + 46] LED continuous light-strips are the right choice for automotive assembly lines. They ensure a uniform and high level of illumination. LED downlights are recommended in bays with ceiling heights of more than six metres.

DIN EN 12464-1 requirements: Automotive industry

Room, task or activity	E_m	UGR_L	U_0	R_a
Body work and assembly	500	22	0.60	80
Painting, spray booth, grinding booth	750	22	0.70	80
Painting, touch-up, inspection	1,000	19	0.70	90
Upholstery, final inspection	1,000	19	0.70	80

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Chemical industry

Depending on the task at hand, process-based production plants in the chemical industry are very different and therefore need individual lighting solutions. Nevertheless, general criteria for lighting can be established. Ex (explosion-proof) luminaires are prescribed for work in areas with explosive substances.

Many chemical production plants are subject to constant observation and monitoring. Sufficient vertical illuminance is crucial here. It is also very important to avoid reflected glare on instruments and fittings. Open containers must be well illuminated down to the bottom.

Take operating conditions into account
In areas with large accumulations of dirt, only enclosed luminaires with a higher IP rating are suitable; they may also have to be resistant to the materials being processed there. Dust-proof luminaires are essential for mixing, grinding or pulverising plants; Ex luminaires must be used if there is a risk of explosion. Furthermore, it should be noted that LED luminaires often cannot be used in areas with high ambient temperatures or harmful gases. Suitable conventional luminaires should therefore be selected for these areas.

The average illuminance for permanently occupied workplaces must be at least 300 lux (lx). Illuminance may be lower for workstations where manual intervention is limited (150 lx), and for remote-controlled facilities (50 lx).

The luminaires should mostly be arranged to provide task area lighting. For activities with challenging visual tasks, the general lighting should be supplemented by workplace luminaires tailored for specific operations. Where necessary, it is important to ensure that the lighting is screen-compatible.

Lighting systems
Continuous LED light-strip systems with appropriate optics are suitable for both low and high bays. Alternatively, linear luminaires can be used for heights of up to six metres, and LED high bay floodlights or high-pressure discharge lamps at heights of six metres and over. Ex luminaires are compulsory if there is a risk of explosion.

Where physical shapes need to be identified or surfaces inspected, individually adjustable supplementary workplace luminaires provide directional supplementary lighting and thus ensure adequate contrast.

DIN EN 12464-1 requirements: Laboratories and clean rooms

Room, task or activity	E_m	UGR_L	U_0	R_a
Processing installations, with				
remote control	50	–	0.40	20
... with occasional manual operation	150	28	0.40	40
... with permanently manned workplaces	500	19	0.60	80
Precision measuring rooms, laboratories	500	19	0.60	80
Pharmaceutical production	500	22	0.60	80
Colour inspection	1,000	16	0.70	90

[47] High bays: Continuous LED light strip systems provide light for paper production.

[48 + 49] Process-based systems requiring occasional manual intervention need at least 150 lux illuminance; at least 300 lux is required for permanently occupied workplaces.

Laboratories and cleanrooms

Many products nowadays are produced in cleanrooms or laboratories due to the increased product quality demands. The lighting system requires a special type of protection and design, and must provide very good light quality.

The idea of the “cleanroom” originated in the field of medicine. Today, there are more cleanrooms operating under such conditions in the manufacturing industry than in the healthcare sector, since the demands on product quality have increased considerably and more and more components are now produced or assembled in cleanrooms.

Demanding visual tasks

In general, visual tasks in laboratories and cleanrooms are much more demanding than in other traditional, craft-based industries. Accordingly, there are very high requirements for lighting quality in laboratories and cleanrooms.

Industries using cleanrooms include the

- Chemical industry with pharmaceutical production facilities, precision measuring rooms, laboratories, rooms for inspection and finishing,
- Semiconductor industry,
- Biotech industry,
- Electrical industry with rooms for fine to very fine assembly work and with rooms for testing and calibration work in electrical workshops,
- Microelectronics industry and the
- Metalworking industry with rooms for very fine assembly work as well as for precision and micromechanics.

There are also numerous cleanrooms in the food industry: for sorting and washing, mixing and packaging products, for delicatessen foods and in research laboratories.

Industrial kitchens can also be designed as cleanrooms. And other facilities with increased requirements, such as laundries and dry cleaning services, can also be equipped with cleanroom technology.

Light for laboratory work

Complex laboratory work places high demands on the quality of the lighting. Lamps with a colour rendering $R_a \geq 90$ are required

in order to make valid colour comparisons. It makes sense to illuminate the entire room with light sources which provide the same colour rendering, even if colour inspections are only made at certain points. In general, high illuminance levels are required in laboratories: 500 lux (lx) is appropriate, with 1,000 lx daylight white light for colour tests.

Many tools and materials have shiny surfaces. It is therefore particularly important to avoid reflected glare. The luminaires of the task area lighting and the workplace luminaires must be positioned and aligned accordingly.

To avoid stroboscopic effects during laboratory work, all light sources should be operated with suitable EBs (in the case of LED luminaires: current amplitude dimmed, or PWM frequency > 2 kHz).

Lighting systems

The “cleanroom luminaire” designation merely indicates the luminaire’s suitability for use in a particularly clean environment. The main priority in a cleanroom is to protect the products from impurities.

The specifications are documented in detail in the relevant DIN EN ISO standards and in quality assurance guidelines such as GMP (Good Manufacturing Practice) and HACCP (Hazard Analysis and Critical Control Points). These standards have a significant influence on the design of equipment in cleanrooms, including luminaires.

In general, the lighting for laboratories and cleanrooms should be closed (high IP rating) and meet hygiene requirements, e.g. through easy-to-clean surfaces that prevent the formation of germs. The above standards and guidelines determine the particle emission behaviour of the equipment in the cleanroom as a criterion for classification. The selection of materials and the optimization of design properties are correspondingly important for luminaires. Recessed luminaires are used almost exclusively.

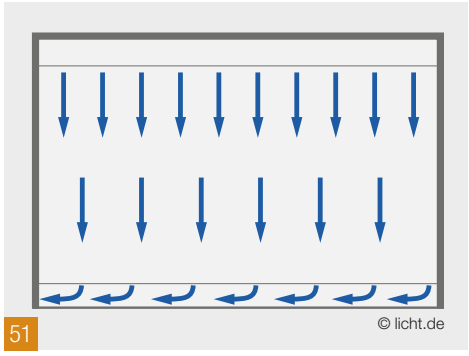
Maintenance of the lighting should be as simple as possible, as it is only carried out by specially trained personnel. Access from above is often provided for quick and easy maintenance without the need to stop production.

Surface-mounted luminaires are also used in exceptional cases – usually due to the space requirements of other media. Ex luminaires are compulsory if there is a risk of explosion.

Two airflow concepts

There are two different airflow systems for cleanrooms: laminar and mixed airflow.

Laminar airflow: The air flows vertically downwards with little turbulence, as in a chimney. Most cleanrooms of this kind are found in the micro and semiconductor industry. IP 40 is usually a sufficient degree of protection for luminaires (see Fig. 52).



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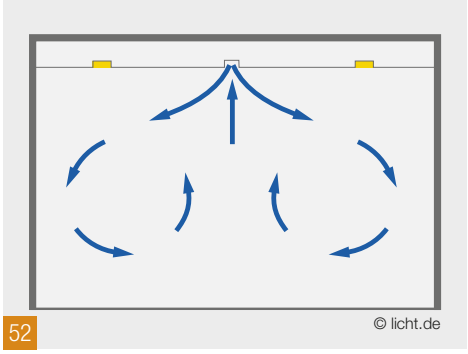
Mixed airflow: The air is distributed in turbulent patterns. About two thirds of all cleanrooms work on this principle, since this equipment is considerably cheaper. Depending on the application, a minimum IP rating of 54 to 65 is prescribed for the luminaires (see Fig. 53).



52

[50 + 53, 54] Illuminance levels of at least 500 lux are required for laboratories and cleanrooms in which demanding visual tasks are performed; at least 1,000 lux of daylight white light is needed for colour inspections. The lighting should be screen-compatible.


53


54

Heavy industry

Heavy industry – mining, iron and steel processing and heavy chemicals – is one of the primary sectors of the economy. Many of the process plants are located outdoors and need to be illuminated there. But some operations take place indoors. Luminaires with a high IP rating, as well as a good number of explosion-protected (Ex) luminaires, are used in heavy industrial plants. Under extreme ambient conditions (such as very high temperatures and levels of soiling), modern and efficient LED luminaires can only be used to a limited degree.

In general, the lighting must exhibit good local uniformity, parts of machines projecting upwards must not give rise to disturbing shadows. In addition, adequate vertical illuminance needs to be provided – e.g. to make instruments easy to read and to guard against accidents on stairs. Narrow and wide-angle industrial LED luminaires are particularly suitable for this purpose.

Light for production facilities
Where production facilities operate without manual intervention, 50 lux (lx) luminance is sufficient for standard compliance. In production plants where dust, smoke or vapours are generated, visual conditions may be severely impaired at times.

A minimum of 150 lx is therefore required. In addition, high-pressure sodium vapour lamps with a poor colour rendering index of $R_a \geq 40$ may also be used. At stationary, constantly manned workplaces, however, the light sources must have at least a colour rendering index of $R_a \geq 80$.

When LED luminaires are used in heavy industry, it is essential that the permissible ambient conditions are adhered to. If there is a risk of condensation, corrosion-resistant luminaires must be used.

Facilities under constant surveillance
Production facilities under constant surveillance require a minimum of 300 lx illuminance. Because ceiling and wall reflectance is usually low, narrow-angle light distribution is important. Accessible hall girders (crane girders) must be taken into account during planning: they must receive enough light to ensure safe access.

Task area lighting is the correct solution for constantly manned workplaces in processing plants. This should be geared to the specific characteristics of the machine and the workflow. The interior of open containers must be well illuminated.

Lighting systems
Luminaires containing high-pressure discharge lamps are a very economical option in (the predominantly) high halls. Combining good local uniformity with high luminous flux per mounting, they permit a smaller number of luminaires, which reduces maintenance costs. Powerful LED industrial luminaires can also be used, provided the ambient conditions permit this. Where necessary, Ex luminaires must be used.

One effective lighting solution is provided by floodlights mounted outside areas with explosive atmospheres. Narrow-angle luminaires in open (IP 20) or preferably enclosed (IP 50) designs are an alternative. A high IP rating for closed luminaires extends the maintenance intervals.

Continuous strip lighting systems with oblique reflectors, which must comply with the IP rating, are suitable for task area lighting at work places.

For optimal adaptation to local circumstances, luminaires should be chosen which permit variable light distribution.

55


56

DIN EN 12464-1 requirements: Heavy industry

Room, task or activity	E_m	UGR_L	U_0	R_a
Production plant without manual operation ... with occasional manual operation ... with continuous manual operation	50 150 200	– 28 25	0.40 0.40 0.60	20 40 80
Furnaces	200	25	0.40	20
Rolling mill, coiling, shear and separating lines	300	25	0.60	40
Control platforms, control panels	300	22	0.60	80
Test, measuring and inspection stations	500	22	0.60	80

[55 + 56] Luminaires for heavy industry must have a high IP rating and (in some cases) also be explosion-proof (Ex luminaires).

57

Plastics processing

Plastics processing involves different production processes, the special features of which must be taken into account in the lighting. As a general rule, flexible task area lighting which is geared to the arrangement of machines is recommended.

The lighting in these areas must be screen-compatible since the machines on all production lines are controlled and monitored using displays. Low-luminance luminaires are the only suitable option here.

Light for injection moulding
Injection moulding machines require supplementary lighting in the area of the clamping units to ensure sufficient brightness for re-tooling. Since these activities only take place intermittently, it makes sense to increase or reduce illuminance as required using a suitable lighting management system. For some products, e.g. parts for medical equipment, injection moulding machines are also used under cleanroom conditions *(see Page 38f)*.

Extrusion
The plastic profiles, tubes or sheets made in extruders require further processing, e.g. cutting to size. Supplementary lighting is needed for the relevant downstream facilities.

Reaction engineering
Potentially explosive propellants are used in some machines and systems for making and foaming plastic parts from reactive components. Explosion-protected luminaires are thus prescribed for these areas.

Enclosed luminaires with a higher degree of protection (IP 54 or IP 65) should be installed in areas with high dust levels. In thermal forming and production processes, the maximum permissible ambient temperatures must also be taken into account, as the ambient temperature can have a great impact on the service life and performance, especially of LED luminaires.

In addition to the European standard DIN EN 12464-1, the German workplace regulation ASR A3.4 and DGUV information 215-210 “Natural and artificial lighting of workplaces” must be observed during planning.

Lighting systems
Production processes and the positions of machines are frequently changed – and the visual tasks along with them. Flexible lighting solutions are therefore the best option for plastics processing. Continuous rows of LED strip luminaires with different light distributions are a favoured option. Frequently, supplementary, task-based lighting is recommended which provides additional light at the workplace itself. A lighting management system that enables quick and easy adjustment of the lighting situation ensures optimum results.

[57] Flexible lighting solutions are the best choice for plastics processing. Rows of LED strip luminaires with a lighting management system represent a convenient solution.

Woodworking

Woodworking involves tasks with different lighting requirements. In addition, the ambient conditions place special demands on the luminaires and their maintenance, as well as on the lighting installation.

Frequent moves between workplaces in the wood processing industry require very flexible lighting solutions. In addition to general lighting, individual workplace lighting helps to ensure that sufficient light is available for the respective visual tasks. On account of the frequent changes, the luminaires should also be glare-free from all viewing angles.

The minimum requirements for illuminance, uniform and glare-free lighting and colour rendering are described in DIN EN 12464, which applies throughout Europe. Accordingly, 500 lux (lx) illuminance is sufficient e.g. for machine work, while 750 lx is required for coating and wood inlay work.

Workstations with high visual comfort
Arranging workplaces parallel to the window wall and to the luminaires ensures good lighting. Saw blades, milling heads or drill bits need to be clearly identifiable; stark shadows impede vision. Reflections on bright metal surfaces represent a further impediment and should therefore be reduced to a minimum.

In addition to ensuring optimum illumination of the actual work areas during woodworking, it should also be borne in mind that stroboscopic effects can arise. Rotating parts may appear stationary, especially when illuminated with low-frequency pulsed light (< 2 kHz). Furthermore, the operators of such machines must take account of the increased maintenance requirements. Dust deposits caused by tiny wood chips can lead to an explosive environment. Maintenance alone is not sufficient in these cases; explosion-protected luminaires are essential here.

Lighting systems
In the past, high-pressure discharge lamps were frequently used in wood processing plants, often with very great room heights. Thanks to LED technology and efficient light-guiding optics or reflectors, there are now very efficient alternatives to metal halide lamps. Adjustable colour temperatures, high colour rendering values and a long service life are the most persuasive arguments for converting the general and workplace lighting.


58

[58] Flexible lighting is required in wood processing plants where there are frequent workplace changes. LED solutions also offer efficient lighting with high lighting comfort levels for high bays.

DIN EN 12464-1 requirements: Woodworking

Room, task or activity	E_m	UGR_L	U_0	R_a
Automatic processing (e.g. drying, plywood production	50	28	0.40	40
Workbench work, gluing, assembly	300	25	0.60	80
Polishing, coating, pattern-making	750	22	0.70	80
Work at woodworking machines (e.g. turning, jointing, grooving, milling)	500	19	0.60	80
Quality control	1,000	19	0.70	90

Warehousing and logistics

Warehouses consist of various areas: loading ramps, shelves or work desks all have different lighting demands. In addition, high roof constructions with high light mounting heights and often narrow aisles must be taken into account during planning. In addition, most warehouses have little or no daylight.

Vertical illuminance is particularly important for high-bay racking: labels on the stored goods and the shelf labelling can only be read quickly and accurately if there is sufficient vertical brightness. The 100 lx to 200 lx (for constantly manned storage facilities) average illuminance set out in DIN EN 12464-1 is therefore normally not bright enough. The industry initiative licht.de recommends installing 300 lx (at least in certain areas) so that labels, delivery notes and storage documents can be easily read.

DIN EN 12464-1 requirements: Warehouse

Room, task or activity	E_m	UGR_L	U_0	R_a
Storage and warehouse rooms	100	25	0.40	60
Dispatch and packing areas	300	25	0.60	60
High bay warehouses, gangways: unmanned gangways: manned	 20 150	 – 22	 0.40 0.40	 40 60
Control station	150	22	0.60	80
High rack	200	–	0.40	60

Light for high-bay warehouses
High-bay warehouses with their sometimes very narrow aisles place the highest demands on uniform vertical lighting. Here, all light control possibilities must be exploited in the form of appropriate narrow-angle luminaires, and wide-angle or oblique luminaires for reading and search tasks.

Warehouse entrances and exits
The lighting of warehouse entrances and exits is dictated by the high accident risks found at these indoor/outdoor interfaces. Marked differences in brightness here can overtax the human eye. The transition from light to dark is particularly critical. By day this is experienced when entering the comparatively dark building, by night when exiting the illuminated building. To avoid accidents, the different lighting levels in the transition zone need to be evened out; this requires a lighting installation which can be switched for day or night-time operation.

Lighting systems
The ceiling height is also decisive in warehouses: continuous LED strip systems are used up to heights of six metres, whereas high-pressure lighting systems can also be used at heights above this. Special light distribution solutions that are suitable for mounting heights of up to 15 metres and that offer uniform vertical illuminance levels are available for both systems. Lighting planning measures must be taken to reduce direct glare when looking up into the shelves.

Luminaires with a higher IP rating must be used for cold storage rooms. This is where LEDs display their superiority over fluorescent lamps; the lighting level does not decrease at low temperatures.

Savings through lighting management
The greatest savings are achieved by systems that provide light only where and when it is needed. Warehouses can be divided into zones. Presence sensors in each zone activate the full illumination when a movement is detected there or when someone approaches. This ensures that people and vehicles can move safely around the warehouse. When a room is not occupied, the light is dimmed to energy-saving background lighting.

Zones should be easy to configure, e.g. using a remote control. The different zones are defined in consultation with the user, and the lighting levels defined for the presence or absence (discreet background lighting) of persons. If the room layout is changed, the zones can be quickly reconfigured using the remote control.

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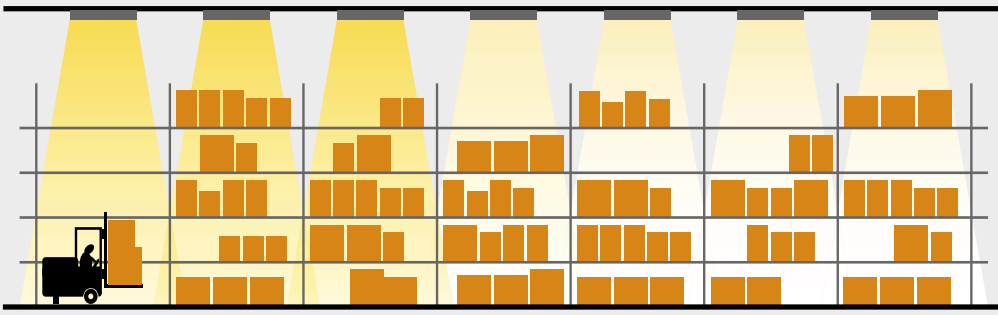
Lighting management in warehouses



63

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[59 – 62] A range of visual tasks is performed in storage areas. Luminaires for high-bay warehouses have special oblique reflectors that render goods and lettering clearly visible.

[63] Lighting management provides efficient “light on demand” in warehouses. Sensors activate full zone illumination whenever people approach. The light is dimmed when no-one is present.

Precision close-up vision and quality inspection

In many areas of industry the technical components are getting smaller and the manual activities are getting more and more demanding and complex. The human eye is being challenged to the maximum. Such applications require very high illuminance levels, often combined with special lens systems.

High illuminance levels and very good colour rendering properties are required of the light sources for precision close-up vision. This is where activity-related lighting, such as that offered by balanced-arm luminaires with optional lens systems, is the right solution.

Light for micromechanics and jewellery production

An average illuminance of at least 1,000 lux (lx) is required for precision and micromechanics work areas. In addition, the R_a colour rendering value must be above 80.

In even more challenging fields, such as the manufacture of jewellery or watches, up to 1,500 lx must be available. A colour temperature of over 5,000 kelvins (= daylight white) is ideal for good contrast vision. Very high demands are also placed on colour rendering in such applications; $R_a \geq 90$ is required.

Direct and reflected glare on shiny surfaces can be avoided through the correct positioning of luminaires and the use of appropriate reflectors and louvres. A light source close to the workpiece is often necessary in order to perform such complex visual tasks – in other words, lighting that is focused on the area of activity. Ideally, these systems are fully adjustable and equipped with an ergonomic balanced-arm system.

64

DIN EN 12464-1 requirements: Near vision

Room, task or activity	E_m	UGR_L	U_0	R_a
Precision and micromechanics	1,000	19	0.70	80
Very fine assembly work, e.g. PCBs, measuring instruments	1,000	16	0.70	80
Electronics workshops, testing, adjusting	1,500	16	0.70	80
Processing of gems	1,500	16	0.70	90
Watchmaking (manual)	1,500	16	0.70	80

[64 + 66] Magnifying luminaires facilitate challenging quality inspection tasks.

[65] High illuminance levels, planar, shadow-free light and very good colour rendering properties of the light sources are required for precision close-up vision. Activity-based lighting that can be flexibly adjusted is appropriate here.

Quality inspection
In general, the general lighting of the production building is rarely sufficient for quality control workplaces where demanding visual activities are conducted. Workplace lighting is therefore indispensable which is installed in addition to the general lighting. Supplementary lighting is also essential where a workplace is overshadowed by other structures or installations.

The lighting system itself depends largely on the material of the test object: the lighting needs to be tailored to suit the surfaces, colours and reflective characteristics. Workpiece dimensions and any resulting shadows also need to be taken into account.

The required illuminance, direction of light and light colour (colour rendering) thus vary depending on the visual task or level of visual detail. If different products are tested at a single workplace, it should ideally be possible to adjust the lighting properties to the visual requirements. A lighting management system is suitable for this.

Planar or punctual lighting
A basic distinction is made between two lighting concepts: planar and punctual lighting. In general, the following are recommended

- planar, shadow-free light for the examination of matt, shiny or transparent objects, e.g. for bumps, dents or warping,
- glancing punctual light for the inspection of surfaces for scratches, cracks or cuts. The resulting shadows make it easier to identify surface structures.

Note: Special care must be taken when using LED array luminaires at workplaces, as these can lead to a changing perception of shape due to the multiple shadows.

Magnifying luminaires for demanding visual tasks
Special magnifying lamps should be used if the naked human eye is not sufficient to perform particularly demanding visual tasks. Such luminaires are ideal for precision testing in research and development or for the assembly of very small components. In many cases, an integrated lens made of glass or plastic provides two to three times magnification which, in combination with plenty of light, ensures relaxed and ergonomic working – especially when repetitive activities are involved. In order to avoid the need for constant adaptation of the eyes, the field of view of the lens should be correspondingly large – approximately corresponding to the distance between the eyes – and distortion-free. Magnifying luminaires are a convenient aid, assuming that they can be adjusted quickly and easily and that the set position is held without swaying.

Lighting systems
The mechanical adjustment of the lighting systems should offer maximum flexibility for the relevant delicate visual tasks, and allow technical adaptation such as dimming or segment switching. This allows shadow effects to be avoided or deliberately created.


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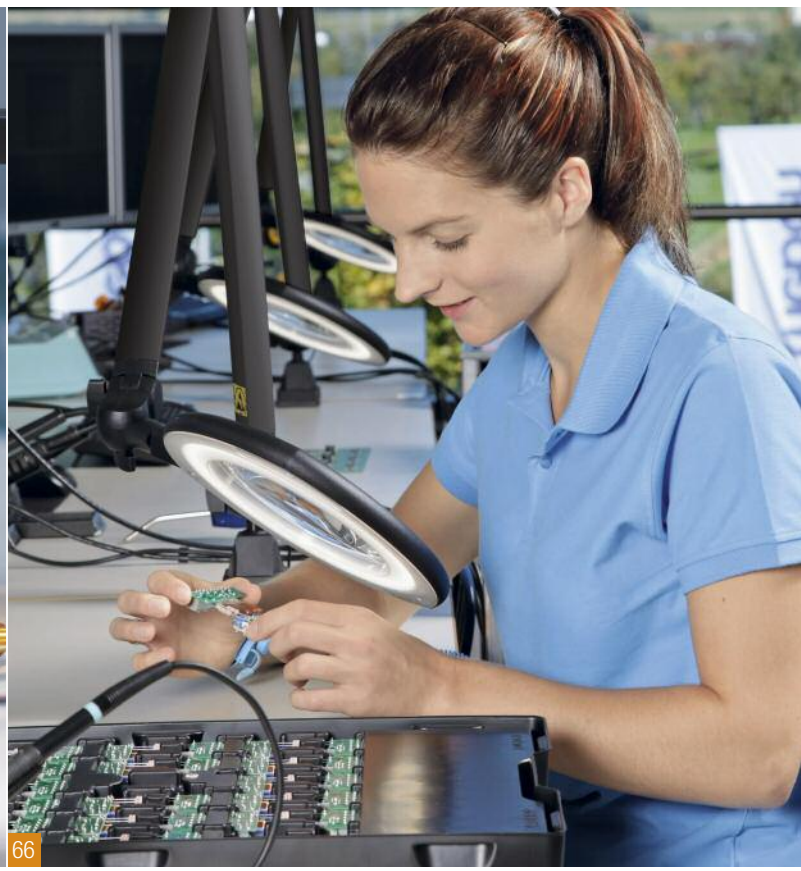
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Printing and Textiles

Large amounts of light are required in printing and textile companies: sensitive materials, colours, images, fonts and fast-running machines call for accurate visual identification. Special attention is paid to the quality of light, especially at workplaces where the quality of print products and textiles is assessed.

Various visual tasks are performed in the printing and textile industries: from simple printing or manual work, such as spinning and twisting, through to demanding visual tasks, such as retouching, designing or quality inspections. The light level and lighting quality requirements vary accordingly. The work involves the processing of fabrics, inks or images – usually also by manual means. licht.de therefore recommends good colour rendering, glare limitation and uniformity of lighting.

Lighting for printers and bookbinders
Small and medium-scale printing works normally consist of two main areas: the actual printing plant with the printing presses, and the bookbindery where the printed sheets are turned into the finished product. For both areas, average illuminance should be at least 500 lx.

Prepress and lithography
Prepress today largely involves working at a computer screen, so protection from direct and reflected glare is a priority. Luminaires need to meet the requirements for display/screen compatible lighting. If necessary, glare protection may be additionally provided by supplementary workplace measures. Average illuminance should be 500 lx.

Further requirements for computer-based image processing are set out in the standard ISO 12646 “Graphic technology – Displays for colour proofing – Characteristics and viewing conditions”.

Skilled manual work and fine visual tasks
DIN EN 12464-1 also recommends a minimum illuminance of 500 lx for skilled manual activities in the textile industry. Finer visual tasks – such as sewing or drafting – require 750 lx. Typesetting, retouching and lithography require 1,000 lx, handling steel and copper engravings requires at least 2,000 lx.

Sufficient vertical illuminance levels are required for large printing and textile processing machines. Such luminaires should be installed parallel to and above the machines. If necessary, lighting can also be installed above the inking unit and before the front edge of the cutting table. Additional lighting for maintenance work on the machines is also useful.

Control and inspection workplaces
Particularly important in the printing and textile industries are the control and inspection workplaces, where illuminance levels of 1,500 lx are crucial. Here the colour rendering index of lamps needs to be $R_a \geq 90$, whereas $R_a \geq 80$ is sufficient in the rest of the room. A colour temperature of between 4,000 and 6,500 kelvins (K) is recommended, depending on the sample. Ideally, it can be varied and adapted to the product being evaluated. Further detailed requirements for colour proofing are set out in the standard ISO 3664 “Viewing conditions”.

licht.de recommends task area lighting for quality inspection workplaces. Indirect or side lighting is appropriate in places where work frequently involves glossy papers, films, etc.

Lighting systems
Flexible LED lighting that supports the various visual tasks is the right choice for printing works and textile companies. The luminaires should be glare-free and individually adjustable for the workplace to avoid reflections on prints, machines and monitors. Flexible luminaires and lighting management systems adapt the light to the requirements of the various visual tasks and machine activities.

Special overhead luminaires providing uniform daylight-quality illumination can be used at control workplaces for multicolour printing. These facilitate difficult visual tasks and permit precise colour control.

For sensitive fabrics and paper grades, attention should also be paid to the choice

DIN EN 12464-1 requirements: Printing and Textiles

Room, task or activity	E_m	UGR_L	U_0	R_a
Cutting, embossing, printing machines, matrix production, paper sorting and manual printing	500	19	0.60	80
Automatic textile printing	500	25	0.60	80
Sewing and fine embroidery	750	22	0.70	80
Type setting, retouching, lithography	1,000	19	0.70	80
Colour control for multicolour printing	1,500	16	0.70	80


67

of light spectrum, and the lighting should be as gentle as possible, with a low UV component.

Especially in the textile industry, some activities also require a high IP rating for the lighting. Spinning and twisting, for example, produce fine dust which can be deposited on the lighting and cause an explosion if the surface temperatures are excessively high. In this case, special Ex luminaires should be used.

Fine paper dust can also arise in printing plants. Luminaire surfaces should therefore be designed in such a way that makes it more or less impossible for dust to accumulate. In dyeing areas and baths, there must also be protection against moisture and resistance to acid and alkaline substances.

Note: Stroboscopic effects on rotating machines, such as those for spinning and twisting, should be taken into account.


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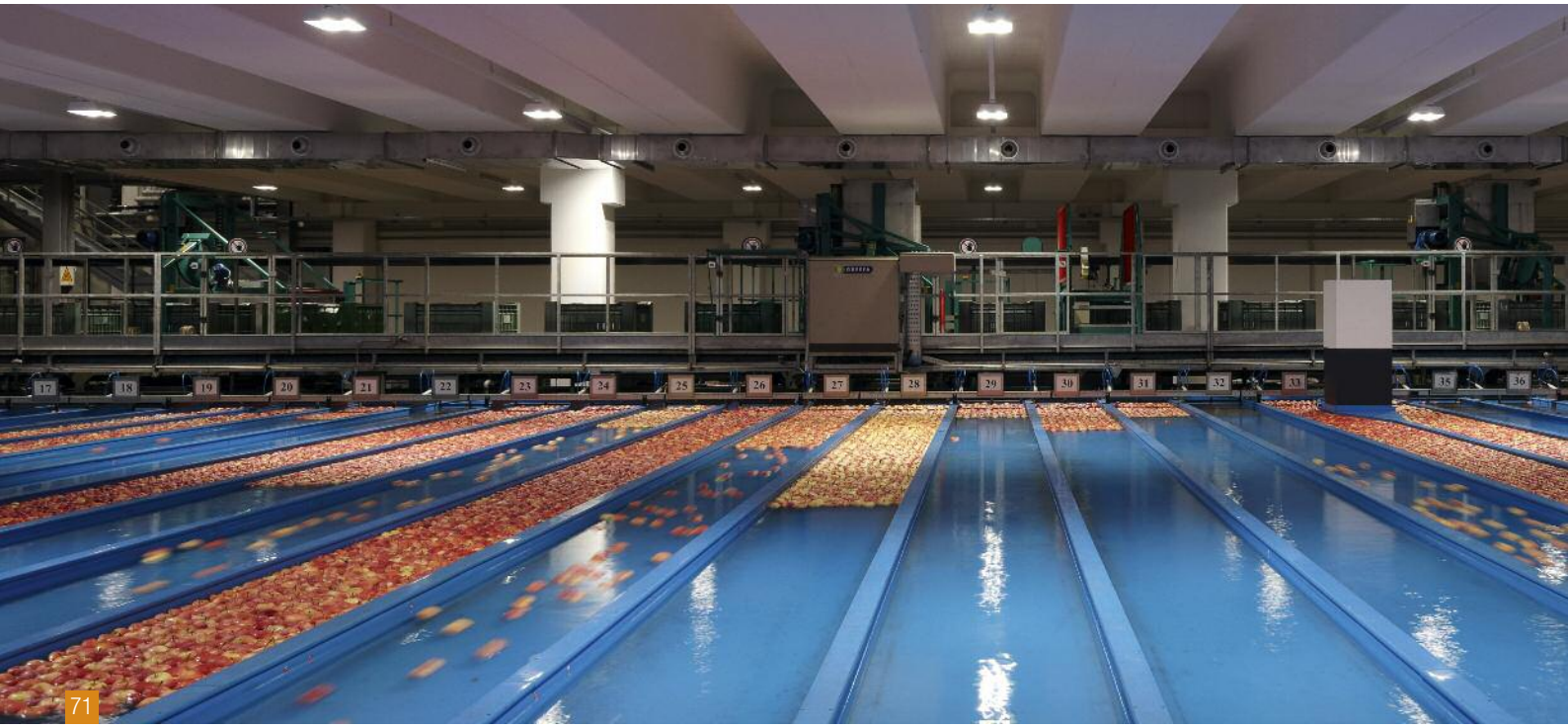
67 – 70] LED luminaires in the form of continuous light strips or individual luminaires are ideal in printing plants and the textile industry. Ex luminaires may be required, depending on the environment.



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Food processing

Cleanliness and hygiene are the most important requirements in food processing. This also applies, by extension, to businesses that make regular supplies to the industry, e.g. cleaning utensils. The choice of bright and friendly colours conveys confidence.

[71] Widespread process automation has been introduced in many areas of the food industry. In this case, lighting the entire work area is the right choice.

[72] In cold stores, special damp-proof luminaires for low-temperature areas should be used – preferably fitted with LEDs because the diodes tolerate the cold very well, unlike conventional light sources.

A good number of operations in the food industry have only low visual requirements. These include processes that are largely automated and only need to be monitored on a random basis at longer intervals. Lighting for the entire work area is appropriate, therefore, for many companies in the food and beverage industry. However, monitoring tasks require not only horizontal but also sufficient vertical illuminance.

Additional workplace luminaires facilitate garnishing and inspection

Where a food processing operation necessitates frequent moves from one workplace to another, all workplaces should be equally well illuminated and the luminaires well shielded to suppress glare in all viewing angles. Room-based lighting is best suited for this. At workplaces where more challenging visual tasks are performed, such as garnishing, or at inspection stations, supplementary workplace luminaires are invariably essential.

The average lighting level for washing, cooking, drying/fermenting and filling is over 200 lux (lx) illuminance, whereas 300 lx is required for sorting and packing work. DIN EN 12464-1 stipulates even more stringent lighting requirements for workplaces and critical zones in slaughterhouses, butcheries, dairies and mills, as well as for inspection work (*see table on page 51*).

Good colour rendering is mandatory

Where food is handled, it is particularly important to ensure good colour rendering. The colour rendering index must be at least $R_a \geq 80$. This also applies to facilities with non-colour-critical end products because it must be possible to assess accurately the freshness of the ingredients used and the product itself at all times.

A sufficiently high red component is useful in meat processing (butcheries, slaughterhouses). licht.de recommends light sources with a colour rendering index of $R_a \geq 90$ which meet these requirements. A uniformly luminous panel with low luminance is used to visually inspect bottles and jars for foreign matter, dirt or breakage. Cans

DIN EN 12464-1 requirements: Food production

Room, task or activity	E_m	UGR_L	U_0	R_a
Workplaces and zones ... in breweries, on malting floors; ... for washing, cleaning, sieving, peeling and filling in barrels; ... for cooking in preserve and chocolate factories; ... in sugar factories	200	25	0.40	80
Preparation and baking areas	300	22	0.60	80
Work places and critical zones in slaughterhouses, butcheries, mills, Dairies	500	25	0.60	80
Cutting and sorting fruit, Kitchen work, production of delicatessen foods	500	25	0.60	80
Product controls, garnishing, sorting	500	22	0.60	80
Colour controls	1,000	16	0.70	90

are tested in special cabins with indirect lighting to avoid reflections. Mirrors make it possible to conduct internal and all-round inspections.

Lighting systems
The food industry attaches particular importance to lighting systems that are easy to clean and maintain, and are shatterproof. Dust or moisture-protected luminaires (and in some cases also explosion-protected luminaires) are required for areas where steam, heat, cold, high humidity, dust or an aggressive atmosphere can occur.

In general, diffuser luminaires with smooth surfaces and internal prism optics or reflectors with wide or narrow-angle mirrors are a good choice, depending on the mounting height. A protection class of no less than IP 50 should be used for dry applications. Damp-proof luminaires of IP 65 or higher must be used wherever regular wet cleaning is carried out. Covering conventional luminaires with plastic enclosures prevents glass fragments from entering the food process.

Food producers and suppliers can have their operations certified. Shatterproof luminaires with an EC No. 852/2004 declaration of conformity can simply be integrated in food industry certification systems. These include HACCP (Hazard Analysis and Critical Control Points), IFS (International Featured Standard) and BRC (British Retail Consortium), all of which specify the quality system and processes in the companies. This also includes the cleaning frequency of the luminaires. When selecting its materials, the luminaire industry ensures high resistance levels to cleaning agents; in case of doubt, however, approval should always be obtained from the manufacturer.

A parallel arrangement of continuous light strips above the work places is the appropriate solution; individual luminaires can also be used for higher mounting heights. The workplaces should be arranged in such a way that light is shone onto the workpiece from above and from the side, with as little shade as possible. Horizontal illuminance must be supplemented by vertical components.


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Cold stores

Cold stores are storage facilities; they require 100 lx illuminance to be standard compliant. Nevertheless, the more light the better: 300 lx – at least in certain zones – is recommended to enable labels, delivery notes and storage documents to be read without effort.

Low-temperature areas place higher demands on lamps, control gear and luminaires. For this reason, special “low-temperature”, damp-proof luminaires must be used. In conventional light sources, the luminous flux starts to fall at 0° C. The reduction can rise to 40 per cent at temperatures of well below zero. This must be compensated in the lighting design. LED light sources, on the other hand, tolerate cold very well.

73

Automobile workshops

Work on cars requires lighting solutions which are tailored to the various activities. Daylight usually only enters the workshop from windows on one side or through a skylight. Special work lighting is required for work on the underside of the vehicle.

[73] In the automotive workshop, continuous LED strip luminaires, aligned with the work areas, ensure maximum lighting comfort.

The activities in an automotive workshop range from simple work such as changing tyres through to painting work and fine adjustment or inspection tasks. A basic illuminance of at least 200 lux (lx) is recommended. The luminaires must be positioned so that the vehicles are illuminated from all sides.

However, the lighting level should be high in areas where demanding visual tasks are performed – e.g. 1,000 lx for paintwork (*see also table p. 35*) – or capable of being temporarily raised. The use of a lighting management system is thus a favoured option. Any incident daylight can then also be made use of – thereby helping to save energy.

Assembly pits and painting work

Luminaires are selected for the respective activity. In workshop pits, the lights are mounted laterally with a high proportion of light shining upwards, thus ensuring that the underbody of the vehicle is also well lit.

It is crucial to keep glare to a minimum. In painting areas, good cylindrical illuminance is just as important as ensuring good colour rendering ($R_a \geq 90$) and as little glare as possible.

Portable luminaires, such as small hand-held units, supplement the lighting system and make it easier to work in inaccessible areas.

Lighting systems

High-bay LED luminaires or continuous LED strip lighting systems are ideally suited for automotive workshops. Luminaires with a higher IP rating (at least IP 65) are required in wet rooms such as washing bays. Painting areas often require Ex (explosion-protected) luminaries.

The chemical resistance of the luminaires – especially of any plastic parts – must always be checked in advance. Is the atmosphere particularly oily? Are cleaning additives used? In these cases, the luminaires must be chemically resistant.

Hairdressing and beauty salons

Having the right light in the hairdressing or beauty salon aids creative work and helps prevent errors. It should also create a relaxing lighting atmosphere that boosts customer confidence.

There is no room for compromise in the beauty business – especially not in the lighting. In an open-design hairdressing salon, general room lighting with additional workplace luminaires is the correct choice. In a beauty salon, however, treatments are mainly carried out in individual booths. Here, the lighting is focused on the work areas.

Lighting for the hairdressing salon
In hairdressing salons, it makes sense to mount the luminaires at heights of two to three metres, parallel to the mirror, about 0.5 metres behind the workplace. Alternatively, the luminaires can also be positioned between the chairs, diagonal to the mirror.

The light of task area luminaires arranged on both sides of the mirror surface is decorative and appealing. It increases the vertical light component towards the chair but, as mirror lighting, must be shadow and glare-free.

DIN EN 12464-1 requires at least 500 lux (lx) for all hairdressing work. This is not sufficient for colour-matching: this requires 1,000 lx illuminance and a colour rendering R_a of ≥ 90.

Lighting for beauty salon booths
In the beauty salon, luminaires are arranged on the side interior walls, but also, depending on the room layout, on or above low partitions. Here, the lighting must be variable and meet the different requirements for high visual performance during treatment and for creating a relaxing atmosphere during the rest period. Accordingly, the light should be dimmable. Luminaires to the left and right of the mirror are useful.

Lighting for sales areas
Lighting accents, e.g. in display cases, enliven the room atmosphere. They can even be coloured, but should not dazzle. Large areas of coloured light or other colour effects popular in salesroom lighting should be avoided at workplaces. However, accentuating light, e.g. from narrowly focused spotlights that direct the light onto product displays, is essential in sales areas.

Lighting systems
Efficient and decorative LED luminaires are the best lighting solution in salons. In hairdressing salons, glare-free mirror lights are obligatory for every workplace. Additional downlights, cove lighting or wallwashers provide individual accents and increase the appeal of the salon.

[74 + 75] Decorative LED luminaires provide efficient and attractive light in hairdressing and beauty salons.


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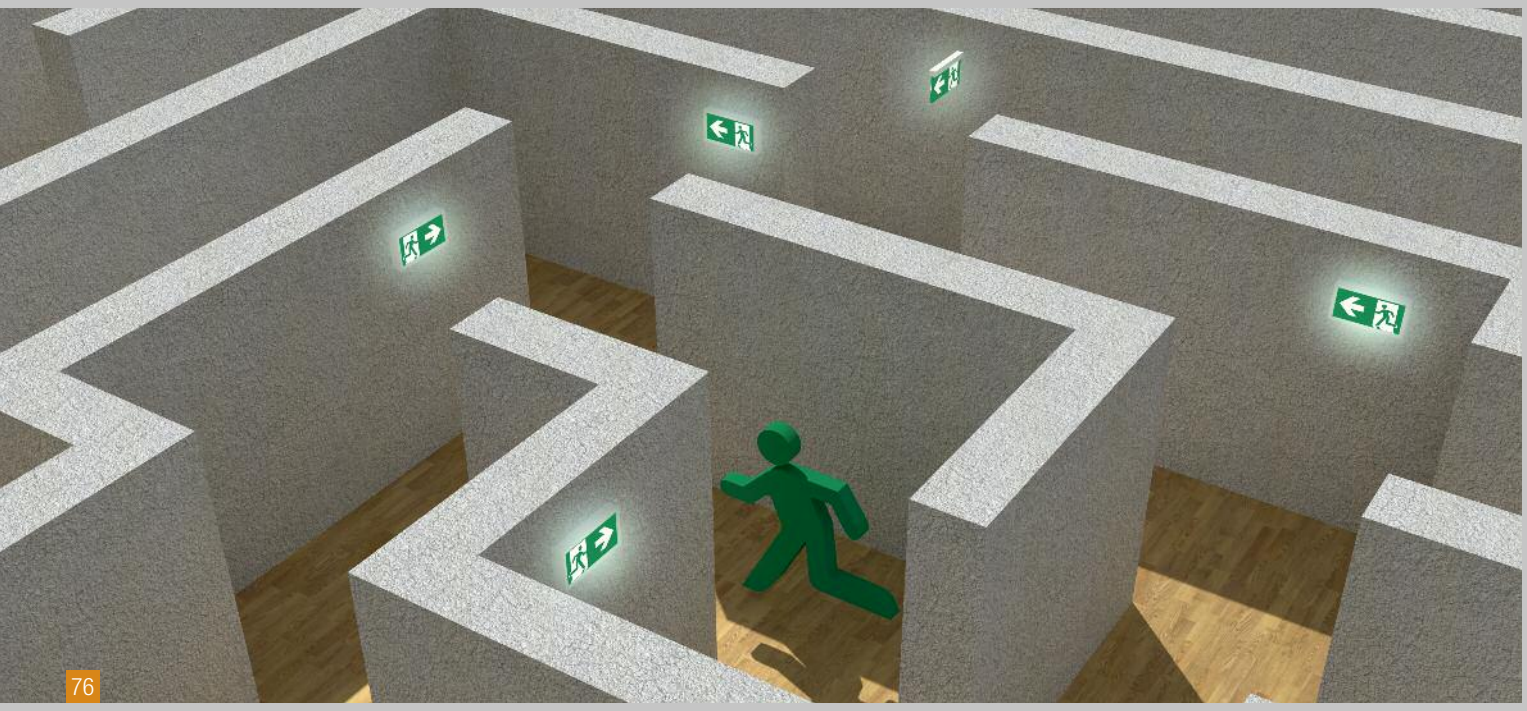

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Emergency and safety lighting

Light and safety are closely linked. If the general lighting fails, the mains-independent safety lighting is activated. It permits safe evacuation from the endangered areas.

Power outages are not uncommon. Although Germany has one of the most reliable electricity grids in Europe, such events can always occur. Emergency and safety lighting then ensures that people can leave a building in an orderly fashion, or that certain work processes can be safely continued or completed. Secure escape routes must be marked with appropriate signs and also illuminated according to normative requirements.

Mains-independent safety lighting
Safety lighting must be taken into account right from the planning phase of a new building. A large number of standards, regulations and directives require designers to incorporate additional lighting which is independent of the mains supply. A fundamental distinction is made between the lighting of escape routes and the lighting of particularly hazardous areas.

The first important decision has to be made with regard to the mains-independence: should the voltage be supplied by generators, a central battery system or by luminaires with integrated batteries as energy suppliers? This basic decision has structural consequences – for the definition of the fire compartments and cables as well as for the spatial requirements of generators or central battery systems. The luminaires must also be compatible with the corresponding emergency power source.

DIN EN 1838 for escape route signs
In the second step, the designer must bear in mind that certain areas with an increased risk have different requirements in terms of the illuminance and uniformity of the lighting. Escape routes are often designed with far lower minimum values for these two aspects. The lighting requirements for escape route signs are described in DIN EN 1838 and relate primarily to the minimum luminance values and the contrast between the white and green areas of the signs.

Operational reliability
In industry, maintenance costs always play a major role in the planning of lighting systems. Safety lighting places special demands on the operational reliability of the lighting system. Regular tests must be carried out. Daily, weekly and monthly inspections of different aspects are prescribed in addition to the mandatory initial inspection.

Furthermore, test criteria specified by standards must be checked annually or every three years. Automatic test features, e.g. in central battery systems, can simplify these tests.

More information can be found in licht.wissen 10 “Emergency Lighting, Safety Lighting”.

Energy Saving Ordinance (EnEV)

The German government's Energy Saving Ordinance is an important instrument of the country's energy and climate protection policy. LED technology and modern lighting management provide the basis for complying with the minimum requirements for the efficient operation of lighting systems.

The German implementation of the European Performance of Buildings Directive (EPBD) is the Energy Saving Ordinance (EnEV). The aim of the EnEV is to achieve building stock which is virtually climate-neutral by 2050. The regulation therefore stipulates the maximum permissible total energy consumption of non-residential buildings, including lighting; this is documented in the energy certificate. The energy consumption required during proper use of the building must therefore be determined prior to any new construction or refurbishment. EnEV 2014 is currently applicable. The energy standard for new buildings was raised in 2016: the permitted annual primary energy consumption for new buildings was reduced by 25 per cent on average.

Basis of the calculation

EnEV 2014 stipulates that the calculation method to be used is that given in DIN V 18599 "Energy efficiency of buildings — Calculation of the energy needs, delivered energy and primary energy for heating, cooling, ventilation, domestic hot water and lighting". Part 4 deals with the net and final energy demand for lighting. Statistical data is used to determine the energy efficiency of the technologies used and the lighting.

Planned amendment

Revision of the EnEV is planned. In addition, the provisions of the Energy Saving Act (EnEG), the Energy Saving Ordinance (EnEV) and the Renewable Energies Heat Act (EEWärmeG), which are currently still running in parallel, are to be merged into a common set of regulations – the Building Energy Act (GEG). One of the reasons for this was the EU Building Directive, which will stipulate the ultra-low energy standard for new buildings from 2019.

At present, old or inefficient lighting systems can still be offset against the energy requirements of other efficient technologies such as heating or air conditioning. The ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie e. V. association is lending its support to the inclusion of lighting systems as technical building systems in the upcoming revision.

This would mean that lighting systems would be evaluated independently in future. And with good reason. No other technical building system can yield similarly high increases in efficiency. The digitalization of light (e.g. connectivity, monitoring, etc.) will continue to increase the energy efficiency of lighting systems in the future.

Another central concern of the ZVEI is professional planning. This includes not only fulfilment of the lighting quality requirements set out in DIN EN 12464-1, but also the drafting of a maintenance plan. It also specifies the cleaning frequency, for example. More frequent cleaning of luminaires allows the system capacity of the luminaire to be reduced.

The maintenance plan has a considerable influence on the energy efficiency of a building. To improve cost effectiveness, maintenance cycles should coincide with the currently required regular repeat testing of the respective electrical systems in accordance with DGUV regulation A3.

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The 2016 ZVEI position paper "Consideration of lighting in the amendment of the Energy Saving Ordinance" addresses this topic in detail.

Checklists

Modernization or new system? Use checklists to make the work easier. The form shown here is used to record the lighting system requirements. It can be downloaded from the licht.de website (www.licht.de) along with other planning aids.

licht.de

Entry Form

Customer / System / Lighting system details

Customer, contact person on site:			
Address / Property:			
Telephone number / e-mail:			
Entered by:			
Use / Ownership:	☐ Owned	☐ Rented	☐ Leased
Type of use:	☐ Office and administration		☐ Industry
☐ Other *(enter)*	☐ Hospital / Retirement Home		☐ Hotel
	☐ Industry / Trade / Logistics		☐ Retail
	☐ Municipal facility		☐ School / Kindergarten
Is a budget available?	☐ Yes	€	☐ No
Project volume / Size	€	m^2	
Is the project in the start-up phase?	☐ Yes	☐ No	
Period under consideration (TCO*) **Total Cost of Ownership*	☐ 3 ☐ 5 ☐ 7 ☐ 9 ☐ 10 ☐ 12 ☐ 15 ☐ 20 years		

lighting system	***System 1***	***System 2***	***System 3***
Use of room *e.g. office, hall, warehouse, workshop*			
Annual operating hours *(alternatively weekly hours)*			
Age of system in years			
Is inventory data available? *(Excel, CAD, drawings)*	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ N
Room dimensions *(L x W x H)*			
Electricity price € / kWh			
Annual electricity costs (€)			
Illuminance in room (lx)			

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lighting system	System 1	System 2	System 3
Luminaire type *1. Louvre luminaire / 2. Downlight / 3. Spotlight / 4. Continuous row / 5. High bay floodlight / 6. Diffuser luminaire / 7. Damp-proof luminaire*			
Luminaires / Lamps per luminaire	/	/	/
Power (Watts)			
Ceiling system *Concrete / Plasterboard / T-System / Metal / Panel*			
Mounting *(MH = mounting height)*	☐ Recessed ☐ Mounted ☐ Suspended _____ MH	☐ Recessed ☐ Mounted ☐ Suspended _____ MH	☐ Recessed ☐ Mounted ☐ Suspended _____ MH
Conventional technology	☐ Yes ☐ Partially ☐ No	☐ Yes ☐ Partially ☐ No	☐ Yes ☐ Partially ☐ No
Is the DIN standard met?	☐ Yes ☐ No ☐ Exceeded	☐ Yes ☐ No ☐ Exceeded	☐ Yes ☐ No ☐ Exceeded
Number of failures per year *(low < 3 % / medium < 10 % / high > 10 %)*	☐ Low ☐ Medium ☐ High	☐ Low ☐ Medium ☐ High	☐ Low ☐ Medium ☐ High
Degree of soiling	☐ Low ☐ Medium ☐ High	☐ Low ☐ Medium ☐ High	☐ Low ☐ Medium ☐ High
Modernization options	☐ Retrofit ☐ Luminaire ☐ + Controls	☐ Retrofit ☐ Luminaire ☐ + Controls	☐ Retrofit ☐ Luminaire ☐ + Controls
Light planning	☐ 1 : 1 ☐ Standard ☐ Concept	☐ 1 : 1 ☐ Standard ☐ Concept	☐ 1 : 1 ☐ Standard ☐ Concept
Are parts defective?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
Degree of protection	☐ IP 20 ☐ IP 40 ☐ IP 65	☐ IP 20 ☐ IP 40 ☐ IP 65	☐ IP 20 ☐ IP 40 ☐ IP 65
Ambient temperature	°Celsius	°Celsius	°Celsius

Notes

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licht.wissen 01
Lighting with artificial light

licht.wissen 01 provides 60 pages of basic information on modern lighting technology presented in a comprehensible and impartial way. It is the first of a total of 20 “licht.wissen” booklets.

[licht.wissen 04] Optimal office lighting promotes a sense of well-being and saves energy and maintenance costs. Booklet 4 contains 56 pages devoted to different applications, and explains which standards need to be observed.

[licht.wissen 09] 40 pages on modernization in commerce, industrial and administration buildings with numerous practical examples which show how modernization 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 19] 56 pages on the biological effect of light on humans: booklet 19 provides information on the latest research findings and presents examples of practical solutions.

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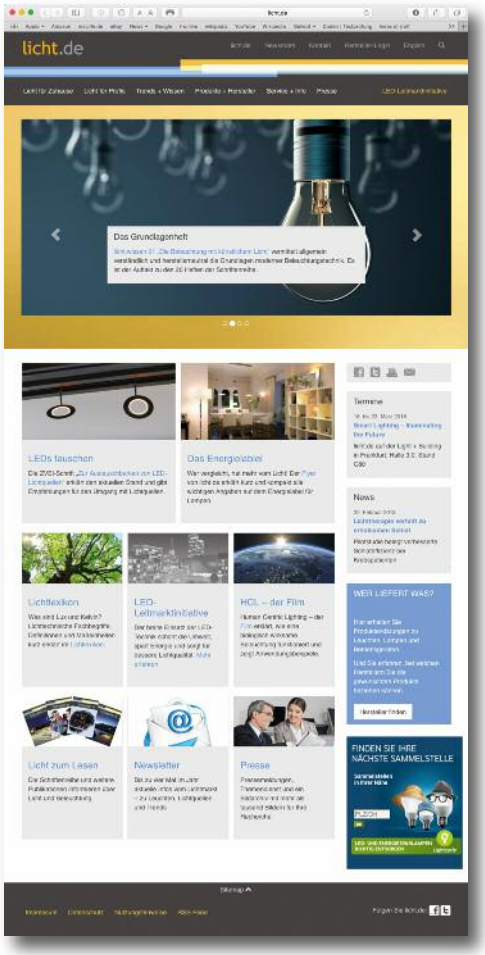

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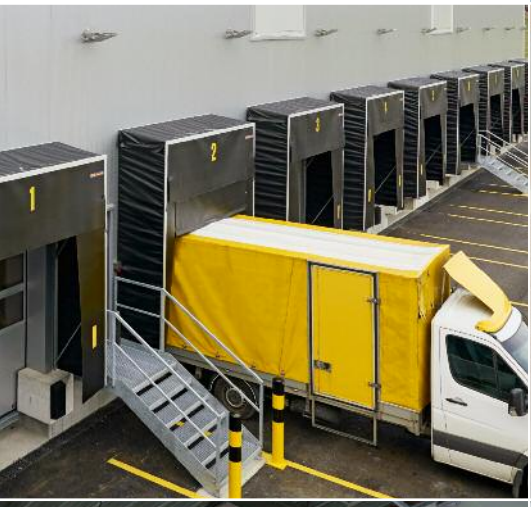

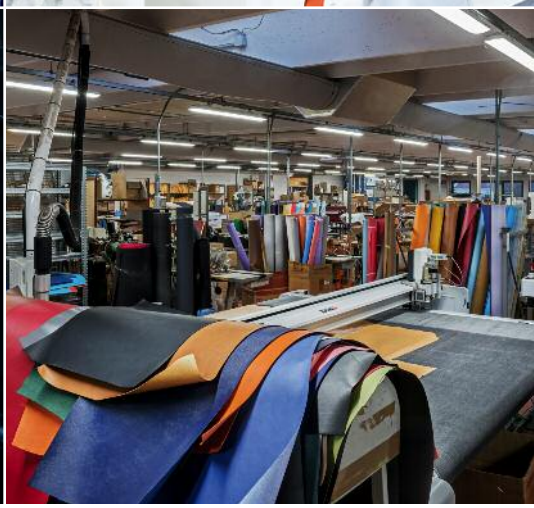

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