

# licht.wissen 12

Light Management







# Editorial

*Light management systems are a key driver of sustainable operations, efficient building technology, and healthy living and working conditions. Their importance increases dramatically in connection with energy shortages, climate change and digital transformation.*

*The dynamic development of lighting management seen in recent years shows how this topic now extends far beyond the control of luminaires. Modern systems integrate sensors including those for detecting presence and daylight. They analyse data such as energy consumption or room occupancy and report the failure of individual luminaires. This allows attention to be paid to aspects such as user convenience, individualisation and predictive maintenance. It also allows synergies with building management systems and smart city developments to be exploited. Light is becoming part of the networked infrastructure aimed at saving energy and making an active contribution to digital value creation.*

*Light management is also being encouraged politically: from 2028, the lighting in non-residential buildings with more than 290 kilowatt hours of installed heating, cooling or ventilation capacity must be incorporated in a Building Automation Control System. This is stipulated by the EU's Energy Performance of Building Directive (EPBD). International climate targets and stricter energy efficiency standards are also sending out clear signals. Today, anyone who attaches importance to sustainable building management can no longer ignore light management systems.*

*However, they are more than just efficiency tools. Light management systems are also drivers of new quality standards. Dynamic lighting control that is adapted to the human circadian rhythm promotes concentration and restorative phases. In working environments, it has a proven track record of increasing productivity; in healthcare, it supports the recovery process; and in cities, adaptive street lighting systems enhance both safety and the quality of life for residents.*

*Managing digital infrastructures requires expertise from various disciplines: electrical engineering, IT, architecture and sustainability management must work together more closely than ever. This integrated approach across different trades presents a formidable challenge for all parties involved. However, it also harbours unimagined possibilities for future applications, for example in the shared use of infrastructure such as sensors and networks for lighting, shading, heating and burglar alarms.*

*Light management has the potential to be a decisive tool in the modern era – for sustainability, well-being and intelligent networking.*

Prof. Meike Barfuß

South Westphalia University of Applied Sciences, Department of Electrical Engineering and Information Technology, Hagen, Germany

## Gender note:

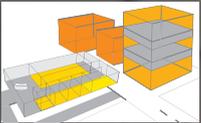
For readability, gender-specific language has been avoided. All personal designations are intended to include all genders.



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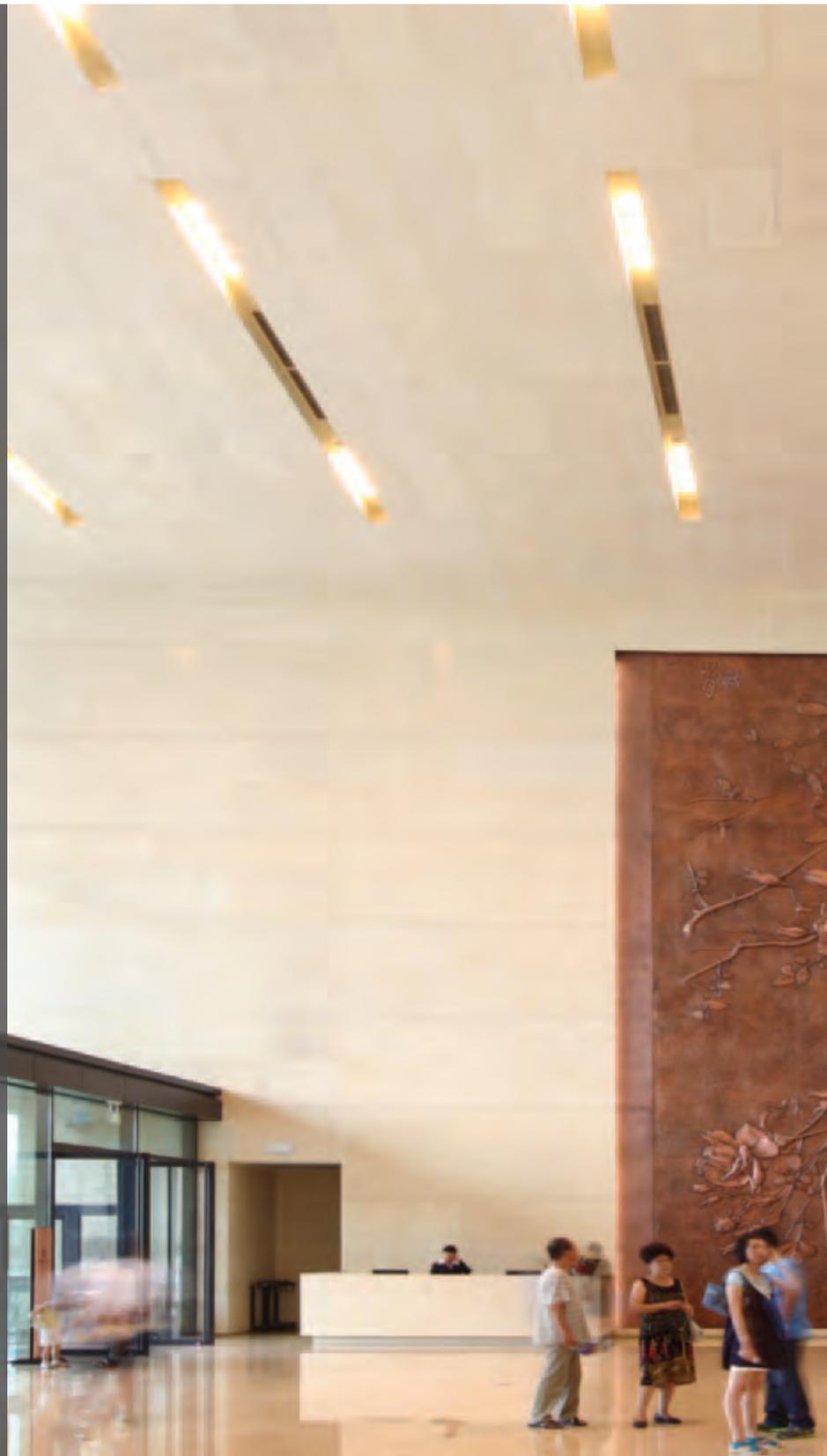
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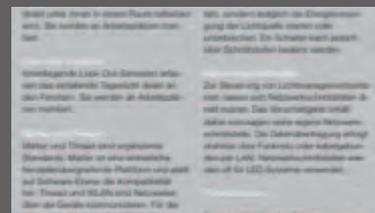
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# Light management for people, living organisms and the environment

Lighting technology is an important part of the technical infrastructure in buildings. With professional planning, it offers operators and users significant added value.

In the past, people simply used to switch lights on and off. Light management systems bring the right light to the right place – at the right time and at the right intensity. Ensuring high illuminance levels for demanding visual tasks, presence-dependent lighting in passageways or selectable ‚discussion‘ and ‚presentation‘ lighting scenes in meeting rooms: lighting today is increasingly being adapted to special requirements and personal needs – up to and including fully automatic, that is, self-learning and intelligent lighting based on artificial intelligence (AI).

## Arguments in favour of a light management system

Light management is the key to achieving greater sustainability in lighting – and will soon be obligatory for certain building categories. Only with automatic control systems can operators take advantage of all the benefits offered by modern light sources, luminaires and control gear. In addition, light is very important as a feel-good factor today.

- The artificial lighting is automatically adjusted to the incident natural light by means of daylight sensors. Compared to old systems from the 1980s, this saves more than 80 per cent energy – and offers much better light quality. And if the lighting is professionally designed, this can yield savings of up to 85 per cent (see page 65).
- Presence and motion detectors activate the lighting only when a room or room zone is actually in use. A timer automatically dims the light to a minimum when no-one is present, or switches it off completely if there are only a few switching cycles per day – an effective way of preventing unnecessary power consumption.

- Programmable lighting scenes can quickly adapt the lighting to changing requirements – a practical solution for offices, catering areas or flexible workplaces, for example.
- Dynamic lighting: the brightness and colour of the light can be varied as required. This allows interesting effects to be created in retail lighting, but also the implementation of Human Centric Lighting (HCL) (see page 80). HCL solutions also take into account the non-visual effects of light and can support people throughout the day: alertness and well-being during daylight hours, rest and recuperation at night.

The tasks of modern light management systems (LMSs) are multiple and varied. They range from local lighting control at individual workstations or in entire rooms through to the networking of systems across different buildings. In large buildings, for example, these tasks can be performed by a comprehensive building management system (BMS). Networking of the individual systems no longer has to be cable-based. Various wireless solutions are now also available.

## Not just a nice-to-have – a must-have for many buildings

Recent legislation is one factor driving the installation or retrofitting of new systems. The Energy Performance of Building Directive (EPBD) stipulates that from 2028, lighting for certain building categories must be integrated into a Building Automation Control System (BACS), in other words, a light management system (see page 62).

## Light management makes economic sense

Most electricity usage stems from professional lighting in schools, training

[01] Daylight-dependent control represents an economical, efficient and sustainable solution wherever large window façades let in a lot of natural light. (Photo: licht.de/Loblicht)

[02] Good office lighting aids communication. According to experts, some 80 per cent of innovations are the product of in-person discussions. (Photo: licht.de/Waldmann)



03

centres, retail and commercial premises, as well as public buildings and transport. Intelligent lighting can therefore make a correspondingly large contribution to saving energy and reducing carbon emissions.

Savings can be made above all if efficient light sources are used and they are dimmed or even switched off depending on the individual requirements and visual tasks involved, on human presence and

on the time of day. It may not be permitted to switch off the lighting in safety-relevant locations, but it may be possible to reduce the lighting level depending on the situation. The system utilises presence detectors featuring manual overrides and integrated dimming, tailored to the specific luminaires and programmed as required, often in conjunction with a time switch. The system can be operated fully automatically with daylight-dependent control, for instance, allowing energy con-

[03] Numerous studies prove the link between good lighting, health and well-being. More and more hospitals, retirement homes and care facilities are therefore using lighting that is simultaneously ergonomic, emotionally appealing and health-promoting. Modern light management supports patients and residents and relieves the strain on staff. (Photo: licht.de/Signify)

Ergonomic goals	Psychological effects	Economic aspects
<ul style="list-style-type: none"> <li>■ Facilitate orientation</li> <li>■ Increase security</li> <li>■ Facilitate use</li> <li>■ Improve comfort</li> <li>■ Increase well-being</li> </ul>	<ul style="list-style-type: none"> <li>■ Strengthen motivation</li> <li>■ Attract attention</li> <li>■ Create moods</li> <li>■ Support branding</li> </ul>	<ul style="list-style-type: none"> <li>■ Save energy</li> <li>■ Reduce costs</li> <li>■ Increase flexibility</li> <li>■ Reduce operating and maintenance costs</li> <li>■ Boost sales</li> <li>■ Increase the value of the building</li> </ul>



sumption to be significantly reduced without any loss of light quality.

This may be achieved at low cost through a simple retrofit.

Initial additional costs compared to a non-controlled lighting system will usually pay for themselves within a short space of time. If operating data is recorded, further potential for optimisation and savings can be tapped – for example

through energy monitoring or the logging of measured values.

### Light management provides safety

Centralised control and the option of remote monitoring of the lighting can also improve security. This can include:

- Storage of maintenance plan in the program
- Fault feedback for defective light

sources, sensors or lighting components in the system

- Protection against break-ins – the security service can simply switch on lights via the light management system.

Safety lighting can be integrated directly into the light management system and take into account requirements for workplaces with special hazards, such as milling or turning machines. If the light management system is planned at the same time as other electrical systems, it can be integrated into the overall building management system.

### Light management creates ambience

Modern lighting technology can control light colours and brightness levels to create different moods or run specific lighting scenes, for example in offices or meeting rooms. Apps can be used to operate, program and control individual luminaires or entire groups.

### Light management supports people

In areas which receive little daylight, light management systems can simulate the brightness and colour of natural daylight. Such lighting which makes use of dynamically controlled illuminance levels and colour temperatures supports people's biological rhythms and has a positive effect on their well-being and performance during the course of the day (see page 80).

#### Example: Control device in office

Automatic daylight control

Concentration

Break

On  Off

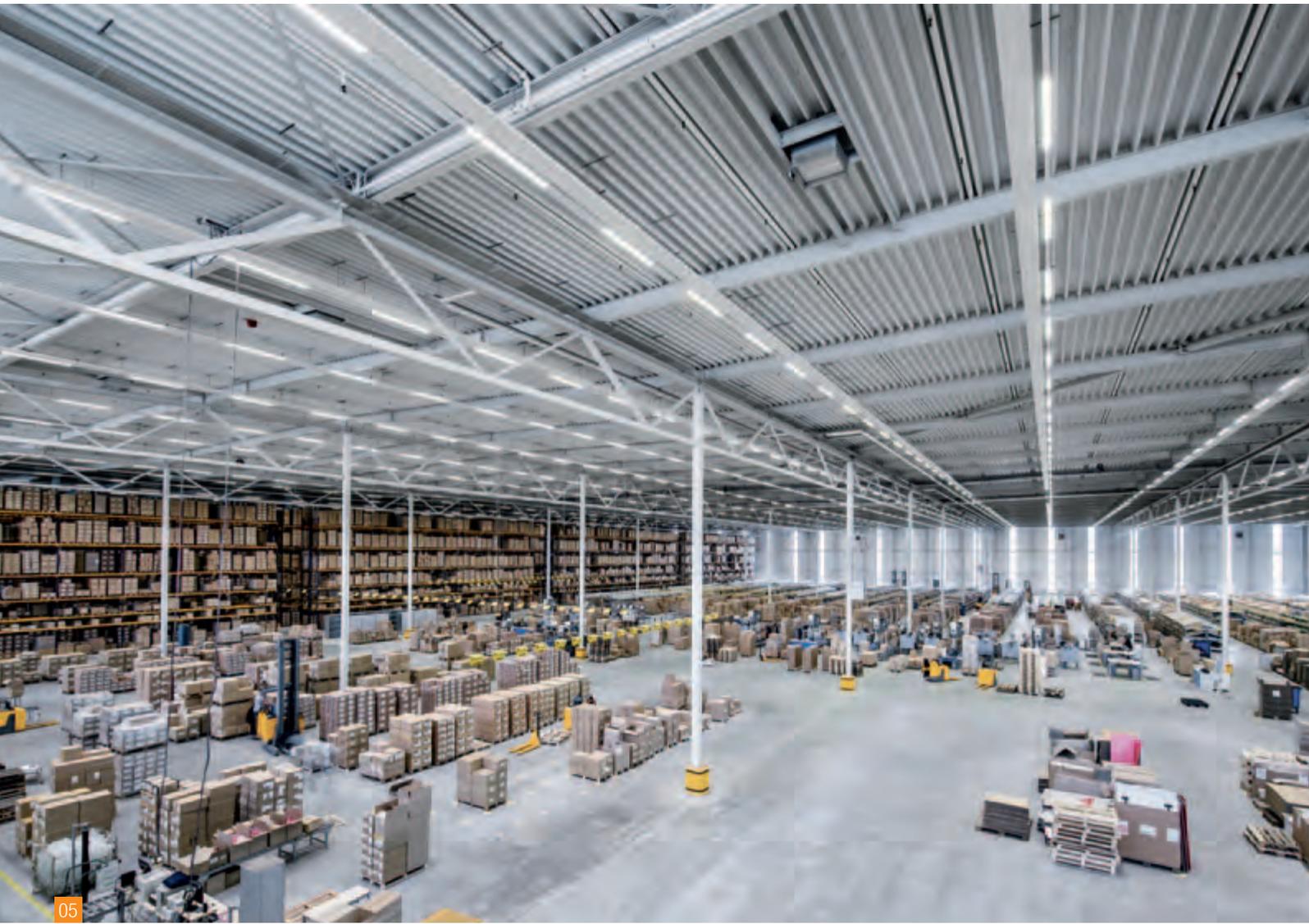
#### Example: Industrial workstation control device

Assembly

Testing

Ein  Aus

[04] Lighting must be intuitive to operate – be it in offices or in industrial buildings. Labelling must be readily understandable for users. (© licht.de)



### Light management offers flexibility

Lighting control systems offer flexibility in situations such as in the repurposing of industrial areas or the redecoration of shop windows. A variety of light colours, different luminaires, different combinations of direct and indirect light enable the versatile use of lighting for a wide range of situations and activities. Light scenes and lighting effects can be easily configured to meet the respective requirements. Individually addressable interfaces such as DALI or Zigbee are often used for this (see pages 78, 81).

and productivity is far more valuable than simply cutting operational expenditure.

Personnel costs account for the largest share of total costs. They are around ten times higher than the rent and a hundred times higher than the energy costs. Even a small increase in productivity or well-being – as the result of better lighting, air quality or acoustics, for example – can yield enormous economic benefits. This is why it often makes more sense to invest in improving workstation quality rather than simply reducing operating costs.

### The 3/30/300 rule

It is even possible to quantify the positive effects on productivity in monetary terms using the 3/30/300 rule put forward by the American real estate company JLL (Jones Lang LaSalle). Facility and property managers use this rule of thumb to compare the cost ratios for energy, rent and personnel per square metre. This illustrates how investing in staff wellness

Costs	Cost type	Factors
3 €	Energy & operating costs	Electricity, heating, water, maintenance
30 €	Property (rent, maintenance)	Rent, cleaning, facility management
300 €	Employees (salaries, social benefits)	Wages, social security contributions, ancillary personnel costs

### Example: The 3/30/300 rule for offices



Source: JLL, A surprising way to cut real estate costs, 2016

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[05] Light management is an efficient solution for introducing 'light on demand' to warehouses: sensors activate full zone illumination whenever people approach. The light is dimmed when no-one is present. (Photo: licht.de/Trilux)

[06] Communal areas in office buildings are inviting places for spending breaks or for waiting, and are ideal for small group discussions. Here, too, people benefit from intelligently controlled lighting which permits the brightness and colour temperature to be finely adjusted. (Photo: licht.de/Esylux)

[07] Workstations must be attractive enough for people to enjoy working there. A study by the US company JLL illustrates the optimisation potential which can be unleashed by applying the 3-30-300 rule. (© licht.de)

# System requirements and planning

When planning a light management system, all parties involved – lighting and electrical designers, electricians, building owners or operators, energy consultants and, if necessary, an architect – should be involved as early as possible to ensure that all components can be optimally configured and that the system offers the maximum benefit.

Describing the lighting solution is typically the first step in the planning process. This defines the task and the required effect of the light in the corresponding application (room). The creative design process yields lighting installations for the entire lighting system that deliver the planned lighting scenarios during operation.

All requirements that could influence the system must be noted before work starts on the concrete planning of a light management system. Once the responsibilities and tasks have been clarified, the lighting, electrical and technical building services planners can start work on selecting the appropriate systems – ideally in close cooperation. The scope and functions of the system can be specified on this basis.

The following must be taken into consideration:

- Building structure (workstation, room, building)
- Customer and user requirements
- Technical requirement: wired or wireless
- Daylight-dependent control or regulation
- Remote maintenance (e.g. for online monitoring)
- Room occupancy
- Time control
- Circadian control
- Operating concept
- Legal requirements of relevance to the planning
- Interface interoperability when connected to an existing BUS system
- Updates, access rights
- Data use and data protection

## Expectations and project goals

Customer and application-specific expectations must be clarified as comprehen-

sively and precisely as possible. The following criteria and quality expectations are also critical:

- Description of light quality
- Resource requirements and consumption
- Green building category
- Degree of innovation in building automation
- Operating data analysis and adjustment
- User-orientated intervention options
- Personalised light

The outlined project objectives are characterised by quality expectations and increased planning effort. Taking the planning of a meeting room as an example, this gives rise to corresponding expenses in the service phases (SPs). In addition, the specified quality targets for the lighting also result in higher prices per square metre.

## SP 0: Goal setting

A need has been expressed for building automation, including lighting control. The need for lighting control can be deduced from the fundamental requirements – such as innovative building, low energy consumption and sustainability (see page 14).

## SP 1: Preparation and briefing

Based on the room schedule, floor areas, and internal functions, a budget estimate is established, including the required standard of finishes and fittings.

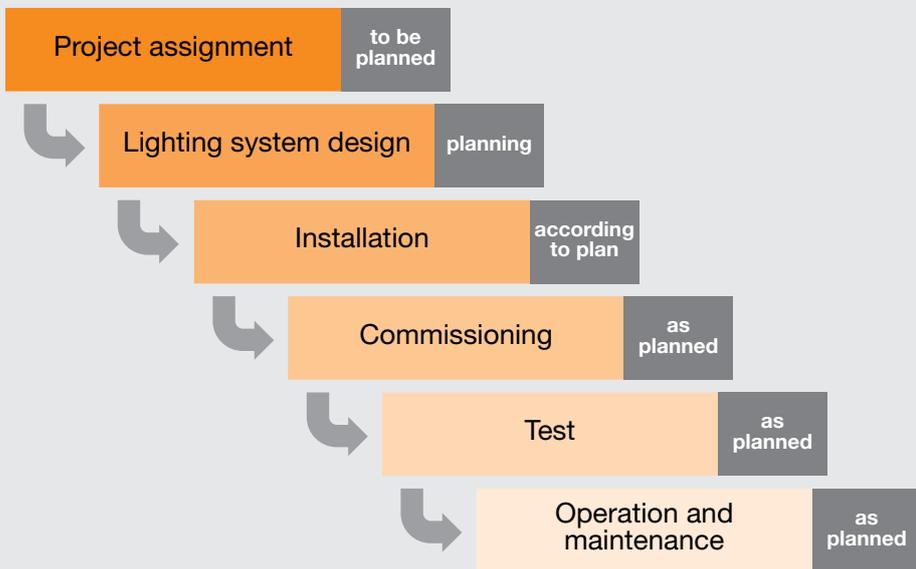
## SP 2: Concept design: Room book

Lighting design is a special service. The costs are estimated based on HOAI DIN 276 cost groups in the building industry, 445-1 General lighting and 445-2 Safety lighting. Higher costs are also to be expected here due to the higher quality.



08

### Lighting System Design Process



09

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

[09] The Lighting System Design Process (LSDP) is described in CEN/TS 17165 'Light and lighting - Lighting system design process'. (© licht.de)

**Example – Meeting room\***

SP 0-Criteria	Individual weighting	Meaning
Sustainability	Very important	In the context of the criteria listed here
Building data Interface	Very important	... because different systems communicate with each other and exchange data.
Energy consumption	Less important	... because the number of operating hours is low, hence a more elaborate lighting design can enhance the atmosphere.
Resource consumption	Critically important	... because the use of fewer resources protects the environment. Includes reparability and durability.
User influence	Very important	... because different components are used in the light scenes.
Light quality	Very important	... for the productivity and well-being of the people in the room.
Design quality	Important	... because lighting and product design as well as the architectural and interior design enhance the quality of the time spent there.
Product quality	Important	... because products of higher quality generally last longer and consume less energy.
Life cycle costs	Very important	... because only taking investment costs into consideration prevents good and far-reaching decisions being made.

\*Requirements vary depending on the project and customer requirements

The lighting concept is developed taking into account the architectural framework conditions and user requirements. The variants are also analysed and evaluated – qualitatively in terms of user comfort and atmosphere, and quantitatively in terms of their cost effectiveness.

This is followed by an exemplary (e.g. graphic) representation for integration into the property planning, information on space requirements, development of a functional diagram or schematic circuit diagram for each lighting system. The next step is to define the basic strategy requirements for the lighting control system (e.g. broadcast or individual control).

**What lighting functionalities and technical features should a meeting room have?**

Additional influences on the design of the light management system result from consideration and evaluation of the following aspects:

- Costs, consumption, service life, installation quality
- Reciprocal influence, e.g. high lighting quality versus consumption
- The light quality criterion depends on the choice of standard lighting or HCL.
- The product quality level (entry, medium, performance) influences costs.
- Lighting control is determined e.g. by HCL, building data and optimisations (settings).
- The degree of building automation also influences the technological lighting solution.
- Lighting and design quality should be accorded greater structural importance in relation to other building trades (with the exception of safety issues).

The following table provides a good basis for dialogue between the client and lighting designer. The answers provide a convincing case for the relevant specification standards.

[10] Meetings are where the groundwork is laid for new projects. The right light gives support to employees, boosting their concentration and creativity. (Photo: licht.de/Waldmann)

## Room requirements (profile for meeting room)\*

Feature or use	Effect on lighting functionality	Lighting conditions	Light setting (scene)
Presentation	<ul style="list-style-type: none"> <li>Speaker lighting is turned on</li> <li>Presentation area and room are darkened</li> <li>Wall lighting is turned on</li> </ul>	Four lighting conditions are required: <ul style="list-style-type: none"> <li>Wide-area work lighting</li> <li>Speaker spots</li> <li>Wallwashing</li> <li>Flipchart, picture</li> </ul>	<ul style="list-style-type: none"> <li>Speaker lighting: 100%</li> <li>Presentation area: 50%</li> <li>Room (work lighting): 30%</li> <li>Wall lighting: 50%</li> </ul>
Meeting	<ul style="list-style-type: none"> <li>Work surface is bright, evenly illuminated with no reflections</li> </ul>	Wide-area work lighting	<ul style="list-style-type: none"> <li>Speaker lighting: 0%</li> <li>Presentation area: 0%</li> <li>Room (work lighting): 100%</li> <li>Wall lighting: 0%</li> </ul>
Event	<ul style="list-style-type: none"> <li>Speaker lighting is turned on</li> <li>Presentation area and room are darkened</li> <li>Wall lighting is turned on</li> </ul>	Three lighting conditions are required: <ul style="list-style-type: none"> <li>Speaker spots</li> <li>Picture</li> <li>Wallwashing</li> </ul>	<ul style="list-style-type: none"> <li>Speaker lighting: 80%</li> <li>Presentation area: 0%</li> <li>Room (work lighting): 0%</li> <li>Wall lighting: 80%</li> </ul>
Cleaning	<ul style="list-style-type: none"> <li>Room lighting is turned on</li> </ul>	<ul style="list-style-type: none"> <li>Wide-area work lighting</li> </ul>	<ul style="list-style-type: none"> <li>Room (work lighting): 100%</li> </ul>

\*Requirements vary depending on the project and customer requirements





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**Light management systems: Light quality versus efficiency**

The table on the right takes exemplary project requirements (indicators) and sets out how they are considered in the lighting solution.

**Qualitative assessment:** Significance for buildings, users and the environment

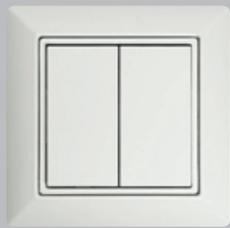
**Quantitative assessment:** Increased value and income

**Light in networked buildings**

Indicators	The Importance of Light
Light quality	The importance of light and lighting quality for the entire building: corporate identity, well-being, acceptance, productivity, error reduction...
Use/User comfort	The lighting system should be as intuitive and comprehensible to use as possible: dynamic and user-oriented, with intervention options and personalized lighting.
Efficiency (energy requirement)	Lighting consumes a significant portion of the total energy demand.
Sustainability	Using daylight/specialized planning fulfils the requirements of the circular economy.
Green building category	Directly influences product selection with regard to quality and other criteria.
Conservation of resources (EPD-documented resource consumption over entire life cycle)	Over the building's lifespan, which is longer than that of a product, resource consumption should be kept to a minimum (utilizing daylight as a resource).
Innovative and highly automated building, including light management	Clear communication via interfaces, use of lighting controls, evaluation of operational data

[11] Large windows let in plenty of daylight. Energy and costs can be saved if the lighting is adapted accordingly. (Photo: licht.de/Helvar)

## Input devices and control elements



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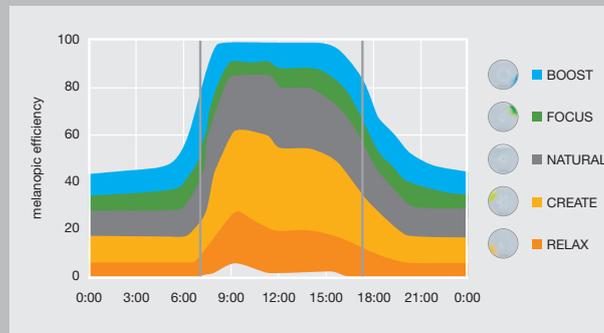
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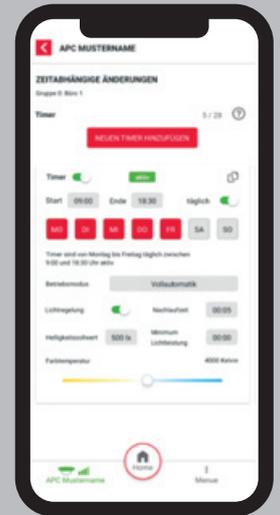
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[12] The illustration shows:  
1) Push-button switch, 2) Rotary dimmer,  
3-5) Touch panels, 6) Remote controls (IR  
or radio), 7) Screenshot of a timer, 8) Switch  
actuators and 9) A smartphone app.  
(© licht.de)

[13] Example of a touch panel for operating the lighting

[14] How the light management is operated in a meeting room depends on the individual system. It can be operated via an app or a control device/operating element. (Photo: licht.de/Ledvance)



# Building structures and their impact

Two questions are particularly important for selecting and using the optimum light management solution: Which tasks should the system fulfil – and where? Three application areas are of relevance at the building level: Workstation, Room and Building.

Each building structure is unique and therefore has different lighting requirements. If selected and used sensibly, light management systems provide for optimum lighting in a wide variety of spaces and zones. Office spaces are divided into work areas and communication zones, each with their own configuration. Industrial buildings usually contain assembly workstations and areas for machines. Each building also has different access areas that are not in permanent use – corridors, stairwells, toilets, storerooms etc. It should be easy to adapt the lighting to changing requirements – and to reprogram it if necessary. A lighting solution which incorporates a light management system can repeatedly be optimised for new constellations and individual requirements.

## Light management at the workstation level

The lighting at the workstation can be controlled individually by manual switching and dimming. Decentralised sensors assigned directly to the workstation can also be used to create automatically adapted lighting conditions. Daylight and presence sensors regulate the lighting in response to incident natural light and human presence. This raises the convenience level and saves energy. Dynamic light control mod-

elled on daylight can also support the human circadian rhythm. In light management systems, luminaires can also communicate with each other wirelessly, for example, thus enabling a ‚swarm‘ function whereby the immediate surroundings are also illuminated with a pleasant basic brightness whenever people are present, avoiding individual pools of light („light islands“).

## Light management at the room level

Several or all luminaires in a room can be networked and grouped as required using the lighting control system. In addition to centralised switching or dimming, grouping also enables a uniform sequence of lighting scenes. This is advantageous for supportive, biologically effective lighting.

## Light management at the building level

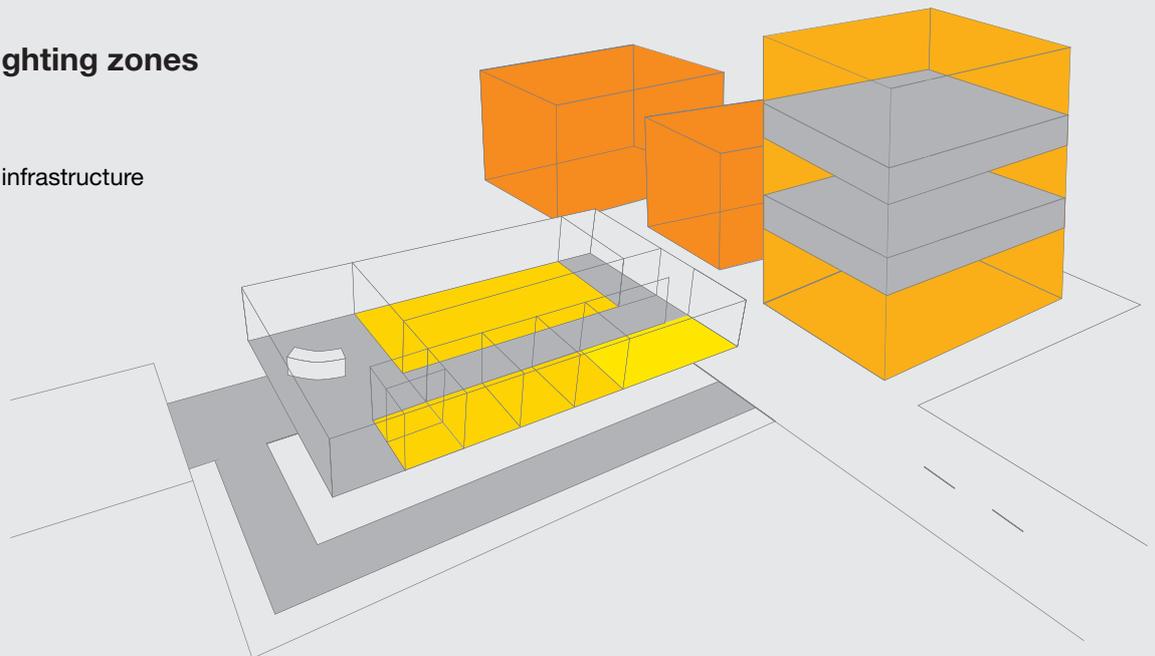
The decentralized data provided by individual luminaires or luminaire groups can be leveraged at the building level for integrated multi-system control and regulation. Heating, air conditioning, ventilation or shading can then be adjusted accordingly. Once everyone has left the room in the evening, for example, external blinds can automatically be lowered and the heating reduced.

[15] In open-plan offices in which only certain parts are occupied, a swarm function prevents the formation of individual light islands. (Photo: licht.de/Loblicht)



### Light management: Overview of different lighting zones

-  Multiple buildings and infrastructure
-  Entire building
-  Entire floor
-  Single room
-  Individual activity area



© licht.de

[16] Appropriate lighting in circulation areas, such as corridors and stairs, avoids adaptation problems and raises the safety levels. (Photo: licht.de/Signify)

[17] Schematic building structure with different lighting utilisation zones (© licht.de)

[18] Each building structure is unique and therefore has different lighting requirements. If selected and used sensibly, light management systems provide for optimum lighting in a wide variety of spaces and zones. (Photo: licht.de/Helvar)





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## Commissioning of the light management system

Once the lighting design for the new system has been finalised – taking into account future requirements, standards and other parameters – any intended interaction with other trades should be checked before the system is actually commissioned. A mutually agreed installation plan can help protect against unwanted surprises.

The lighting design must be supplemented by an electrical design which meets the relevant electrotechnical standards. It also defines the necessary emergency and safety lighting for the building and integrates the system into the building infrastructure. This allows other trades or maintenance groups to interact with the light management system, if this is necessary.

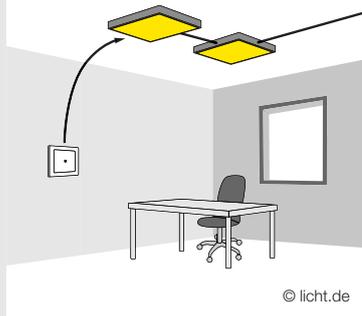
Comprehensive documentation in the form of an 'installation plan' must be created, as the installation and parameterisation on site are not usually carried out by the same people who draw up the lighting and electrical design. It should also be noted that the electrical installation is usually carried out before the light management system is commissioned. Depending on the system design, luminaires must be connected to the power supply and – in the case of wired communication systems – also to a BUS line. Any deviations

from the installation plan that arise on site due to structural conditions must be documented. Once the electrical installation is complete, it is recommended that a general function test of all electrical connections and the installed BUS cables be conducted, in addition to a technical acceptance test of the entire system. This avoids a potentially time-consuming search for faults in the electrical system at the time when the light management system is commissioned.

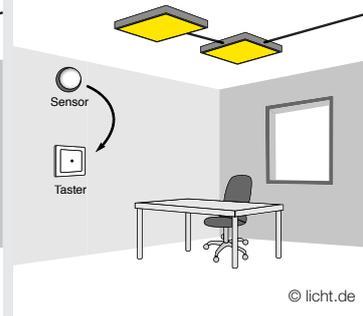
It is also important to take the following into account when setting the commissioning date: light management systems behave differently during commissioning; for instance, luminaires may switch on and off or flash during addressing. This could disrupt normal operations (in an office, for instance) or make them impossible (in a hospital, for example). In any case, rooms and buildings cannot be put to regular use before it is ensured that the emergency light-

[19] Daylight sensors measure the incident natural light and only add enough electric light to provide adequate illumination of the workstation. (Photo: licht.de/ Zumtobel)

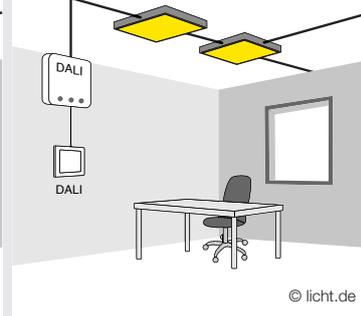
## Manual light control



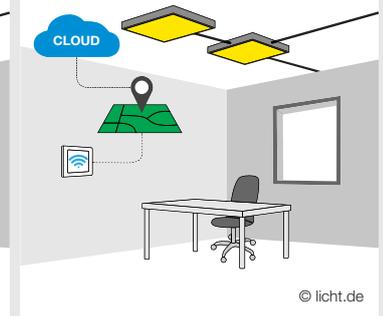
## Stand-alone lighting control systems



## DALI lighting control



## Cloud-based, geo-referenced lighting control



Manual controls, such as simple light switches, require no special commissioning. Their functionality is ensured by proper installation.

Stand-alone systems with extended functions usually include sensors with no manual overrides. Energy savings and greater user comfort can be achieved through one-off, local programming.

Management systems require centralised, networked logic components. They enable higher-level control, comprehensive parameterisation and targeted maintenance of the entire system.

Components can be localised and individually programmed via the cloud. Once the lighting components have been installed, they are connected to a network (wired or wireless connection). The entire system is then linked to a cloud platform.

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ing functions reliably. Some light management systems offer a quick start for rapid commissioning using predefined factory settings.

The parameterisation can be carried out by an installer or a system integrator. Before starting, however, it is important to check or define exactly which luminaires or luminaire groups should respond in which situations, based on which trigger and at what time. The options vary depending on the light management system selected and relate mainly to energy efficiency, convenience and safety. Examples include:

- **Time settings** can define when and in which mode the lighting system should operate.
- If **presence detectors** are fitted, constant light control based on presence and daylight offers the greatest energy-saving potential.
- **Scenes** can be pre-defined and called up at the touch of a button to ensure that the lighting is adapted to meet the requirements for specific activities.
- The parameterisation of **orientation lighting** in a corridor or of a **swarm function** in an office can avoid completely dark zones and increase occupants' feeling of safety.
- A **daily routine** based on the Human Centric Lighting concept – including dynamic changes in light levels and colour

temperature adjustments emulating the course of the sun – can use the biological effect of light to boost well-being and productivity.

How a luminaire or luminaire group should respond can be defined in the light management software. The procedure for such parameterisation depends on the light management system selected.

### DALI-based commissioning

DALI is a widely used system. It stands for 'Digital Addressable Lighting Interface'. Here, a digital protocol is used to connect light sources by means of electrical cables and control them via a BUS system. The parameterisation starts with the identification (addressing) of all DALI BUS devices. In addition, the DALI-2 standard permits the integration of input devices such as push-buttons and presence or motion detectors via a DALI BUS.

Uniquely identified luminaires and input devices can be assigned to one or more groups. The desired settings are then made for individual luminaires or groups. It is advisable to document all settings in detail.



The preliminary DIN CEN/TS 18036 standard must be observed when commissioning lighting systems; it also describes further aspects.

### Cloud-based commissioning

Cloud-based commissioning of lighting control systems is a modern and efficient solution that allows the central management and flexible optimisation of lighting infrastructures. Modern systems also increasingly rely on digital twins or BIM models. These allow parameterisation to be carried out independently of the physical location of individual elements. If further automation is required, the end devices are provided with geo-references and the digital identity is linked to the actual position in the system. This approach enables the digital definition of entire projects – including functionality, groupings and interfaces – during the pre-construction phase before deploying them to the physical site. All that needs to be done on site is to link the real-world devices with their virtual equivalents in the cloud. This shortens commissioning times and saves costs. Step-by-step commissioning is also possible; in this case, a fully functional system is available immediately after installation.

[20] A push-button is the simplest form of light control. It can be coupled with a sensor and connected to a light management system via DALI. Cloud-based systems are also available. (© licht.de)

# Monitoring and maintenance for long-term functionality

Demands on lighting control systems have changed dramatically in the past few years. In addition to conventional functions such as switching and dimming, there is increasing demand for the retrieval and monitoring of usage and status information. This data is important for maintenance of the system and optimisation of operational customer processes.

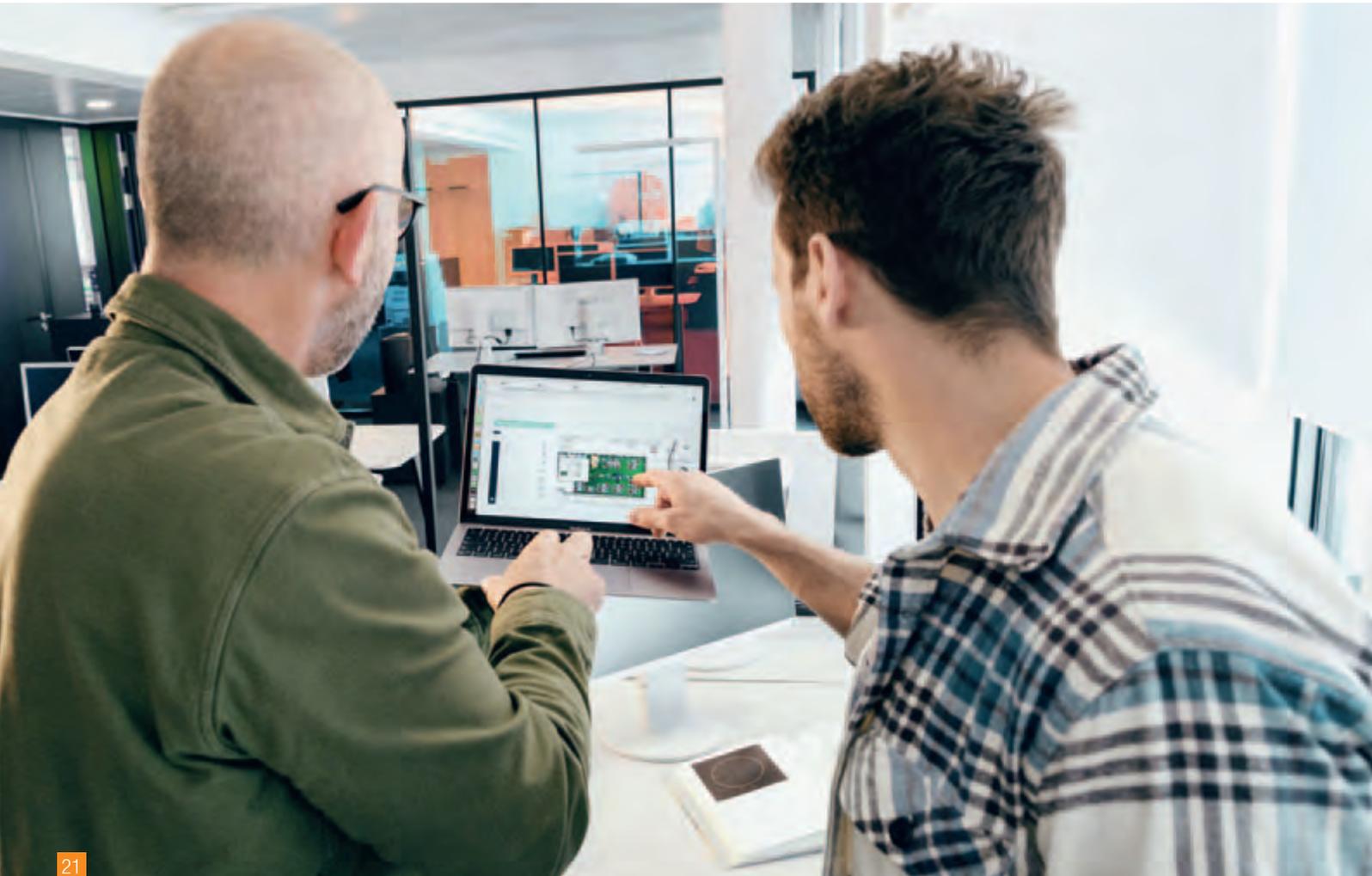
[21] Luminaires can be regrouped, or parameters such as day length and time can be configured for daylight control in the settings of lighting management systems. (Photo: licht.de/Waldmann)

System operators can access and manage their monitoring platforms from anywhere in the world. This is of particular interest for companies with multiple buildings or locations. Data is simply retrieved via an app or a dashboard in the Internet browser. Important notifications, such as those concerning lighting failures, can be transmitted to the relevant departments in real time. In addition, regular reports can be generated

on the overall status of the lighting system – with DALI (parts 251, 252 and 253), for example.

## **Maintaining and expanding functionality**

New tools have significantly changed the work steps involved in maintenance. Routine maintenance work can now be planned in a way which takes damage or defect notifications into account.



On-site maintenance includes visual and functional checks as well as the replacement, repositioning and cleaning of lights and sensors. The importance of software maintenance is increasingly rivalling that of physical hardware maintenance. Updates are carried out via the Internet connection and nobody needs to be physically present.

### Reliable operation through maintenance contracts

For lighting control systems that receive software and function updates, an appropriate maintenance contract should be in place to ensure continued operational reliability. Service providers usually perform their tasks remotely, with no travel costs being incurred.

Contract models such as Light as a Service (see page 80) also ensure ongoing

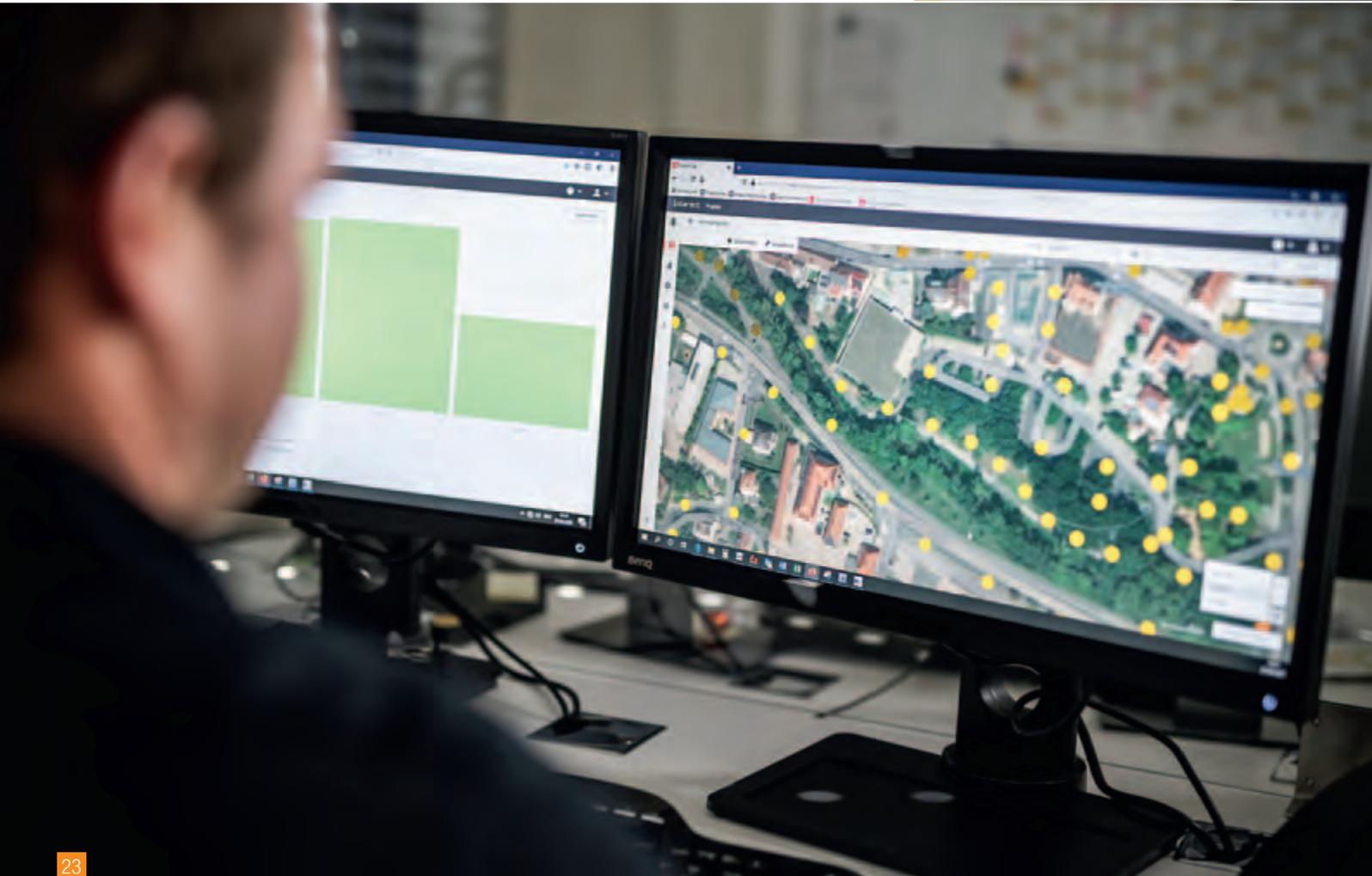
operation and functional maintenance; they include regular optimisation to ensure maximum efficiency and performance. The increasing use of digital and automated processes in the maintenance and servicing of lighting systems is one reason for the growing interest in cloud-based light management systems.

[22] All rooms are controlled via a tablet. In addition to control via daylight and presence sensors, pre-programmed light scenes can be recalled or individual Bluetooth-enabled luminaires can be addressed. (Photo: licht.de/Erco, photographer: Sebastian Mayer)

[23] Light management systems collect lighting usage data, react flexibly to changes, and highlight potential for optimisation in the system. (Photo: licht.de/Signify)



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# Light management in the office – functional and motivating

Desk work, meetings, video calls – office work involves multiple changes of activity throughout the day. Office environments which put people and their needs first provide the best basis for successful work. Light management supports employee well-being and their ability to concentrate by providing user-friendly lighting that is individually adjustable.

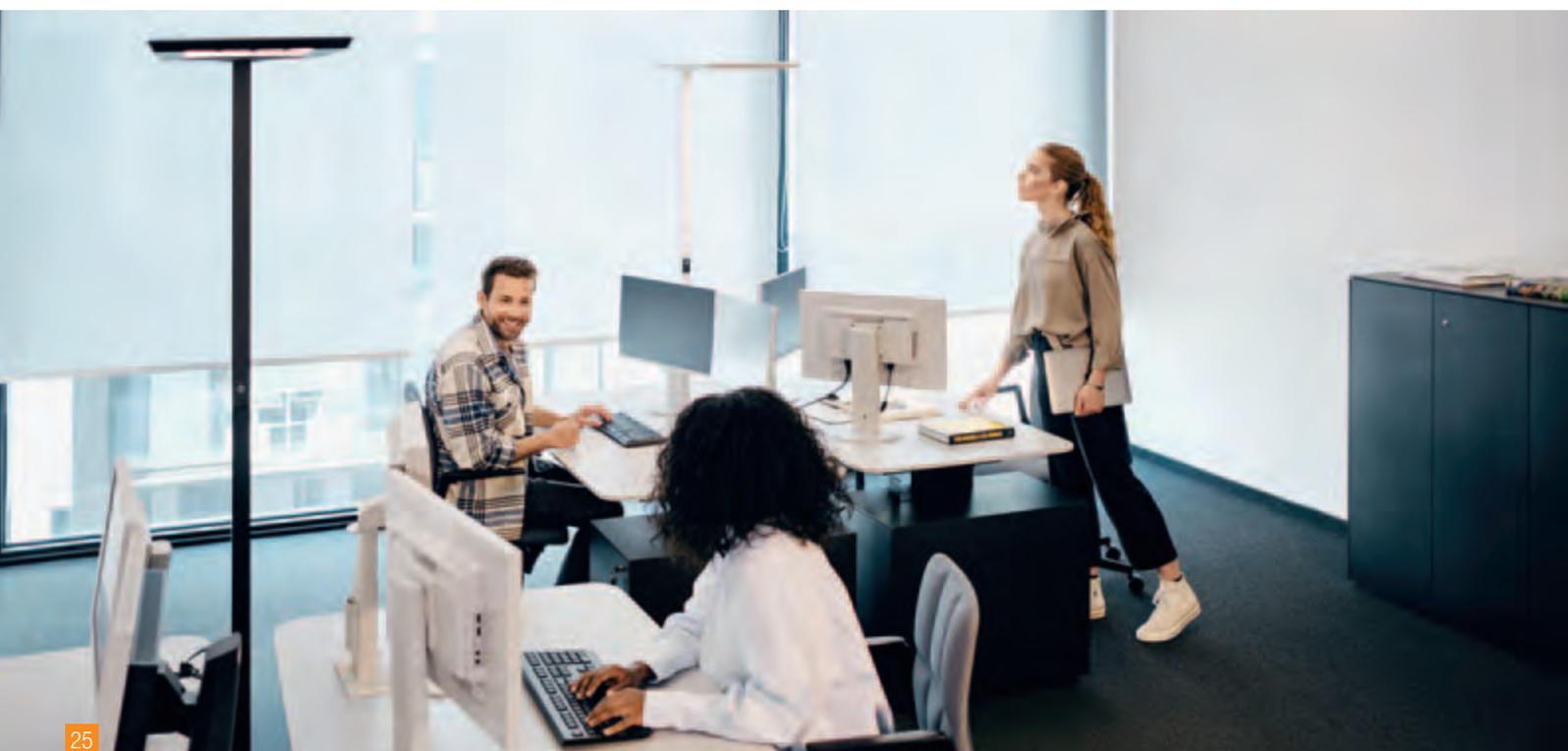
[24] Free-standing luminaires blend discreetly into the office interior. At the same time, they allow flexible reconfiguration of workplaces. (Photo: licht.de/Waldmann)

[25] Free-standing luminaires provide additional light in group offices, while blinds protect from glare. (Photo: licht.de/Waldmann)

These systems control and regulate the lighting based on actual demand, presence detection, the time of day and the natural incidence of light. In group and open-plan offices, different presence times can create 'light islands' that illuminate one desk while leaving the rest of the room darker. Light management systems whose luminaires are assigned to different areas or groups and operate in a swarm avoid this. If one luminaire in a group registers a human presence, it reports this to the other group members, which then illuminate the immediate office environment to a pleasant basic level – for greater safety and an improved room ambience.

## Flexible light for meetings

Lighting control in meeting and conference rooms opens up the possibility of flexible, function-related lighting (see pages 12-17). Different light colours, luminaire types and the use of direct and indirect light in various combinations can be deployed for a wide range of situations and activities – lectern lighting for presentations, lighting for projector presentations, functional lighting for concentrated work or stimulating lighting for creative brainstorming. Light management systems allow for the implementation of predefined light scenes and effects customized for various applications, offering intuitive operation at the push of a button.





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## Networking

Similar to the swarm function (see page 81), corridor linking is a further function of modern lighting control systems. It is mainly used in buildings with many rooms and adjoining corridors – such as in offices, schools or hospitals. Such linking automatically illuminates the corridors as soon as movement is detected in an adjacent area. For example, if someone enters an office and this movement is registered by a presence sensor, the system sends a signal to the adjoining corridor. This is then automatically illuminated – even if no movement has yet been registered there. This ensures continuously illuminated and safe transitions from the rooms to the corridor. The light in the corridor then often remains switched on at a reduced

level but is then faded up when movement is detected. It is only switched off when all the linked rooms and the corridor are no longer occupied.

This function is extremely convenient, needs-based and economical – and helps increase safety levels in transit areas. In technical terms, corridors are typically linked via networked systems such as KNX, DALI or modern wireless solutions that enable flexible and centralised control.



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### Efficient lighting for corridors and stairs

DIN EN 12464-1 and DIN V 18599-10 categorise corridors and stairs as circulation areas. With a relative absence rate of 80 per cent, these areas are ideal for motion-controlled lighting, which offers significant potential for energy savings. Even where there is plenty of daylight in corridors and staircases, daylight-dependent control usually makes little sense, as it would only be active 20 per cent of the time. A threshold switch – that measures the daylight and only switches on the artificial lighting when it detects movement and there is insufficient natural light – is more appropriate here. It is generally advantageous if lights switch on automatically because corridors are also transportation routes and users often have no free hand for activating a light switch or push-button. Nevertheless, very few people are happy to dispense with them completely. Manual switching should then override the automatic system.

The range detected by the sensors must be broad enough for the light to switch on reliably when someone enters the corridor through any door – and only switch off again when the corridor has been empty again for a defined period of time (see

page 79). Alternatively, the lighting level can be reduced to a basic value when no one is present – for example in corridors with a large number of corners and where precise sensor-based detection is difficult.

### Relaxing light for non-work and communal areas

Non-work areas such as canteens are used for revitalisation – people should be able to relax and recharge their batteries there. Lighting based on human-centric principles can contribute to this by dynamically adapting the illuminance and light colour based on the time of day. The usage times in these areas are often relatively clear-cut, meaning that presence detection with automatic sensor-based light switching represents an effective solution.



Optimal office lighting promotes a sense of well-being while saving energy and maintenance costs. licht.wissen 04 presents various applications, and explains which standards need to be observed.



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[26] In this futuristic company head office, there is little difference between the lighting levels of the circulation route and the meeting room. (Photo: licht.de/Helvar)

[27] Sensors perform multiple tasks – including daylight measurement, motion or presence detection. (Photo: licht.de/Ledvance)

[28] Light sensors measure the amount of incident daylight on a reference surface. If the illuminance falls below a pre-determined threshold, artificial light is switched on as needed and then continuously adjusted or regulated. (Photo: licht.de/Esylux)

[29] In many companies, the kitchen also serves as a rest area. Retro-look pendant luminaires illuminate the worktop and dining table, while spotlights light up the pictures on the wall. (Photo: licht.de/Bruck)



# Smart learning

Light management supports not only students of all ages but also their teachers. It can be used for various purposes ranging from supporting circadian rhythms and creating lighting scenes for specific visual tasks in the classroom through to automatically adjusting the light levels.

[30] School buildings are products of their time and reflect the trends of the period. They must meet both structural engineering and technical equipment requirements. (Photo: licht.de/XAL, photographer Kurt Kuball)

[31] Taking the entire service life of the lighting system into consideration, LED luminaires represent the most economical option. (Photo: licht.de/Ledvance)

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

If there is not enough daylight available deep inside the room or in the dark sea-

son, it can be supplemented with suitable luminaires and light management. Modern lighting is now a key hallmark of quality in educational institutions. The aim is to achieve high lighting quality with the lowest possible energy consumption. Light management systems with daylight sensors switch on artificial light as needed to achieve the necessary brightness in the room. In combination with presence sensors, this can further optimise the energy efficiency of the lighting.

## Presence detectors help save energy

Classrooms are not in constant use throughout the day, however the lights are often left on and energy wasted during free periods and breaks. A lighting





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[32] The foyer is cleverly utilized as both a library and a communal area. Bookshelves should be well-illuminated across their entire surface. (Photo: licht.de/Helvar)

control system with presence detectors solves this problem in a convenient and energy-efficient manner. It switches the lights on and off automatically when people enter or leave the room. The same principle can save a lot of electricity in corridor lighting because the corridors are only rarely used during lessons when pupils are in their classes. It is better to dim the lighting to a minimum than to switch it off completely. This avoids frequent switching, thus increasing safety while also extending the service life of the lighting (see page 29).



### Intuitive light scenes

Where light management systems really come into their own is in rooms with constantly changing use. Lighting scenes tailored to different activities and teaching situations can be called up easily via the control display – for seminars, lectures or media presentations, for example. Light management and lighting scenes should be planned with the same level of detail as the lighting concept itself. They must be intuitive to operate and also allow users to manually override scenes and automatic functions, such as presence

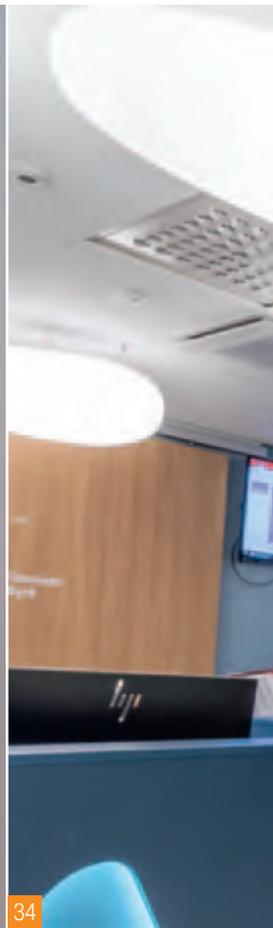
detection and lighting regulation. Many preconfigured or preconfigurable systems for educational institutions already permit this.



In 2023, the industry initiative licht.de published licht.wissen 02 ‚Learning in a New Light‘ in response to the considerable demand for refurbishment in educational facilities.



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## Safety and independence in care and healthcare facilities

Numerous studies prove the connection between good lighting, health and well-being. More and more hospitals, retirement homes and care facilities therefore have lighting that is simultaneously ergonomic, emotionally appealing and health-promoting. Modern light management supports patients and residents and helps reduce the workload of staff.

Light has a medicinal effect on sick people by lifting their mood and promoting recovery through non-visual effects. Patients usually see little or no daylight during a hospital stay. They rarely or never go outside, and their bed is not always by the window. Lighting which has a non-visual impact (see page 80) has a positive influence on biological processes in the human body – for example, in the form of particularly bright light that promotes waking phases, or as dynamic light which adapts to the course of daylight, supporting the patient's sleep-wake rhythm with different illuminance levels and changing colour temperatures. Such lighting solutions also help reduce the workload of hospital staff. Therapy times and care re-

quirements can be reduced if the patient's circadian rhythm remains stable.

### Light in retirement homes

Age-related conditions place high demands on the lighting in care homes. Many residents have poor eyesight. Furthermore, many of them suffer from various forms of dementia. Their movements are unsteady and they have a high risk of falling. Lack of activity can lead to increased drowsiness during the day and restless nights. Practical examples show that, in addition to sufficiently bright light, biologically effective lighting contributes significantly to increased activity and well-being during residents' waking hours. Furthermore, fewer sleeping pills are



needed and the burden on care staff is reduced.

### Self-activating lighting for residents' rooms and communal areas

Automatic lighting makes good sense for patients, residents and staff. The light management system assumes control of the basic lighting at night and ensures safety on circulation routes. Presence or motion detection automatically raises the lighting level when people are present. This can also be used in situations when emergency medical care needs to be administered. Human Centric Lighting is particularly useful for improving the day/night rhythm in the areas used by the residents. Additional lights can be controlled individually to create a pleasant and appropriate atmosphere.

### Night lighting for corridors and circulation areas

There is a reduced risk of accidents if stairs, leading edges and uneven surfaces are clearly recognisable. This can be achieved, for example, by night lighting that switches on when motion is detected. Elderly or sick people feel much safer if they can orientate themselves with ease.

Increasing the vertical illuminance makes it easier to recognise faces, for example, which helps increase residents' sense of personal well-being.

### Calming lighting for examination and treatment rooms

Medical staff should have access to different lighting pre-sets during examinations which have a soothing effect on patients. Lighting scenes generate the right atmosphere for each particular medical procedure. Before and after the treatment, the general lighting should not produce glare and should not create excessive contrasts.

In care environments, hardwired systems are superior to their wireless equivalents because they are less likely to interfere with other (e.g. medical) devices and can be operated from fixed stations, such as switches or wall panels.



Lighting has to fulfil high demands in the healthcare sector. licht.wissen 07 contains the relevant regulations and highlights on 64 pages how light can contribute to recovery.

[33] Senior citizens spend more time indoors than younger people. Their lighting requirements change frequently during the course of the day. The lighting should therefore be correspondingly flexible. (Photo: licht.de/Signify)

[34] Corridors must be well lit so that visitors can find their way around quickly and easily. Illuminated walls convey a feeling of security, counteract the 'tunnelling effect' and have a positive influence on people's sense of space. (Photo: licht.de/Helvar)

[35] Patient rooms have a range of lighting requirements, including light for examinations, and bedside reading lights. It must therefore be possible to activate each luminaire separately. It should always be easy to select the right lighting situation at the touch of a button. (Photo: Shutterstock/Luminares RZB)

[36] Some patients' physical limitations make it desirable to use motion detectors to switch the lighting on and off. (Photo: IKE/Tom Bauer/Luminares RZB)

# Productivity and flexibility in industry

Productivity is the top priority for industrial companies. Lighting must therefore be economical and functional – and ensure a safe working environment. Flexibility is a decisive criterion when choosing the right light management solution. In times of ever faster innovation cycles and greater product diversity, it is crucial to be able to reorganise or expand production areas at short notice.

Good lighting and light management contribute to greater efficiency, productivity and occupational safety in industry. If there is a change of use, it must be easy to reprogram the lighting flexibly, so that the entire lighting system does not have to be redesigned.

## Customised lighting for inspections and manual tasks

Visual tasks are particularly demanding at dedicated workstations for manual labour, inspection and testing. Older employees have more exacting lighting requirements. They should be able to raise the light levels of their own luminaires locally. The workplace lighting standard DIN EN 12464-1 also uses context modifiers to support the selection of higher illuminance levels when specific conditions are met. Assembly work is easier if the right colour temperatures for the respective type of assembly and materials are used. At manual workstations, brightness and light colour can be adjusted as required if the lighting offers ‚Tunable White‘ functionality.

## Special lighting for automated areas

Fully automated areas usually only need to be accessed for maintenance purposes. It should therefore be possible to switch on the work lighting manually in these areas. In normal operation, the machines work autonomously and the illuminance level can be greatly reduced. However, optical sensors including cameras require higher light levels.

## Shift work

Many people who work shifts in industry suffer from a lack of sleep. Their natural sleep rhythm is impaired. Research into the effects of light during shift work recommends lighting control based on the human-centric lighting concept with

dynamic brightness and light colours – similar to the natural progression of daylight, thereby creating a distinction between day and night. In general, warm white light colours should be used in the evening and at night – at high illuminance levels, if necessary.



licht.wissen 05 shows how optimally planned lighting installations facilitate ergonomic working while saving energy and costs.

[37] Inspection and quality assurance workstations demand increased performance from the eyes. Needs-based lighting can help here. (Photo: licht.de/Waldmann)





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## Ambiance and appeal for retail and museums

Customers and visitors are immediately attracted to products and exhibits which are presented in the right light. Such eye-catchers can boost sales. Energy-efficient lighting systems and flexible, easy-to-operate controls are the prerequisites for appealing presentations of goods or exhibits.

Lighting plays a major role in sales areas. Here, light serves not only as a creative, sales-promoting element, but also fulfills important functions. For example, it can be used to mark central walkways, or as safety lighting to guide people to the emergency exits.

### **Daylight harvesting and the protection of sensitive goods**

Goods in apparel and food retail are sensitive to light, which is why large windows or roof lights are seldom used in these envi-

ronments. Daylight is popular in many other retail sectors, such as car dealerships and DIY stores. Wherever large window facades let in natural light, light management systems can utilise the daylight to reduce the artificial lighting levels and achieve a corresponding reduction in energy consumption.

In the entrance and shop window areas, by contrast, the illuminance needs to be increased as the daylight levels rise. The bright light draws the attention of passers-



by and visitors to the goods. At night, the lighting control automatically reduces the illuminance to ensure that passers-by and residents are not dazzled. Motion detectors are useful in less frequented areas. Here, it is sufficient to reduce the illuminance and prevent the space from being plunged into complete darkness.

**Flexible lighting for presentation and special display areas**

Flexible, dimmable and colour-changing lighting concepts are ideal for making adaptable use of retail areas, such as for product changes in pop-up stores. Luminaires can be used to provide general or accent lighting, depending on which product portfolio is being presented. Modern light management systems allow simple reprogramming and offer intuitive operation.

**Variable lighting in museums and exhibitions**

Light management can also be used to showcase the works of great artists. Coloured or dynamic white light, for example, is ideal for attracting attention. Simple adjustment of illuminance and colour temperature is often required in areas with changing exhibits or different exhibitions. In this case, luminaires whose light colour and brightness can be easily controlled represent the right choice. Motion detectors can be useful in museums in cases where exhibits should not be exposed to potentially damaging artificial light for unnecessarily long periods. The exhibitors are only illuminated when visitors are present. Today's light management technologies also allow anticipatory lighting along visitor walkways – a design modification of the corridor function (see page 79). This also represents an interesting solution for exhibitions.



licht.wissen 06 explains the key factors involved in retail lighting.

[38] LEDs offer significant benefits in retail; their low UV and heat emissions are gentle on sensitive foods. (Photo: licht.de/Helvar)

[39] Lighting showcases exhibits and spaces by guiding the viewer's perception. Brilliant light and good colour rendering ensure that details are clearly visible. (Photo: licht.de/Signify)



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## Ambience and comfort for the hospitality sector

Imposing lobbies, stylish restaurants and cosy rooms: guests should feel comfortable at all times in all areas of hotels and other forms of accommodation. Lighting systems with lighting control create a pleasant atmosphere and allow conference and event rooms to be used flexibly.

Light emphasises architectural features, gives structure to lounge and entrance areas, provides accents and separates circulation and quiet zones. Light management systems with programmable light scenes can also incorporate daylight to save energy and conserve resources.

Maintaining the smallest possible carbon footprint is also good for the establishment's image. Varying the illuminance is the optimum method if exhibits, company logos or other special features need to be accented. Dynamic and sensor-based lighting guides visitors through circulation



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areas by adapting the brightness and colour.

### **Cosy yet functional lighting for hotel guest rooms**

Individually styled rooms use tunable lighting – adjustable in colour and brightness – to boost guest well-being. Light management systems offer light scenes that can be organised in groups and called up using suitable operating devices. And when nobody is in the room, presence and motion detectors switch the lighting off automatically.

Mains-independent safety lighting is mandatory for emergencies. In rooms and corridors, the lighting control system will

ensure compliance with the relevant standards and regulations.

### **Relaxing light for wellness**

In wellness areas, everything is geared towards helping guests relax and recover. People can relax more fully if the lighting follows the natural light during the course of the day. Further effects and light colours can provide accents. The lighting can be easily adapted to individual wishes and preferences thanks to largely automated program sequences and intuitive user interfaces.

### **Tasteful lighting for bars and restaurants**

A restrained level of general lighting in restaurants promotes a relaxed ambience

[40] Lighting control systems offer tailored scenes – ranging from festive illumination to utility lighting for cleaning. (Photo: licht.de/Ledvance)

[41] In hotel rooms, luminaire design and colour temperatures should be coordinated with the interior, and illuminance levels should be adjustable for the respective visual tasks. (Photo: licht.de/Molto Luce)

[42] A fully addressable DALI lighting control system in the canteen creates a special user experience. Defined luminous intensities emphasise the biophilic design of the building. (Photo: licht.de/Helvar)

[43+44] In the morning, uniform area lighting ensures pleasantly homogeneous brightness. The diffuse lighting mood has a rather cool, fresh effect at 4,000 Kelvin. Later in the day, the focus is on providing warm white lighting for individual tables. (Photo: licht.de/Erco, photographer: Alexandra Lechner)

while maintaining essential visual comfort. Food and drinks can easily be discerned if the tables and seating places are properly accented. Additional spot lighting is recommended at the bar or counter – which can be taken care of automatically with a light management system. Higher illuminance levels, for example for cleaning, can be called up at the touch of a button. Lighting scenes can best be modified by trained specialists – including remotely via the cloud. After all, fewer journeys will further reduce the carbon footprint.

### Flexible lighting for conferences and events

Many hotels have a range of differently sized function rooms that can be used in a variety of ways: during the day as a conference, meeting or lecture room, in the evening and at night as a party location or dance floor. Light management systems represent an ideal solution for this. Pre-programmed lighting scenes can easily be recalled by hotel staff using a remote control, control panel, push-button or app to quickly adapt the room lighting to the respective use.







# Light management in architectural lighting

Architectural lighting has long since transformed itself into architainment – a mix of architectural and entertainment-orientated lighting. Attractive lighting concepts with modern luminaires set the scene, structure the facades and buildings, revitalise the cityscape, shape the image of the area and help protect wildlife.

Effects from the entertainment world can also be borrowed for the lighting of buildings, bridges, monuments and landmarks. Different optics can be used to provide accents, bathe surfaces in atmospheric light and create a whole range of different effects for buildings based on a range of 16.7 million colour options. Light management systems effectively highlight buildings in the evening, for example by means of:

- Colour-changing effects on façades
- Highlighting of architectural features such as niches, alcoves, projections, ornaments and figures
- Focal point/laser pointer effects that highlight particularly important aspects.

**Three decisions** need to be made when selecting luminaires and systems:

## 1. Choice of light colour – white or coloured?

LED luminaires with white or coloured light can be activated or dimmed. Dynamic lighting always needs a corresponding control system. RGBW luminaires (RGBW = red, green, blue, white) offer even more possibilities, providing a range of colours in addition to white tones – from simple colour selection to colour changes and dynamic sequences to complete light shows. The extended colour spectrum offered by multi-channel (e.g. 4/5-channel) luminaires enables the lighting to be specifically adapted to the existing materials, for example yellow light for warm materials such as wood, and more

bluish light for cool materials such as concrete, steel or glass.

## 2. Automation: ‚Set and forget‘ or flexibility?

ponents to systems designed for flexible use. Flexible lighting systems offer a range of control, from simple manual switches to sophisticated, sensor-driven interactive effects. This ability to quickly adapt the lighting has become increasingly important in recent years. Today, façade illuminations or projections often bathe buildings in the colours of national flags for special events – projecting the colours of the Ukrainian flag onto the Brandenburg Gate, for example. Another example is the rainbow colours on the media façades of the major football stadiums.

## 3. Installation: Highlighting entire buildings or emphasising individual elements

Buildings can be highlighted in different ways: by illuminating them in their entirety or by emphasising individual elements. The following possibilities exist:

- Switching individual lights or groups of lights on or off based on a concept (e.g. DALI)
- Static dimming of individual luminaires or groups according to the lighting concept (leading-edge/trailing-edge phase control)
- Dynamic control, pulsing and dimming of surfaces (DMX/Ethernet)
- Display of video content on surfaces using a pixel system (Ethernet)

[45] Whether for religious services, special celebrations, or cleaning – smartly controlled light management ensures light whenever and wherever it is needed. (Photo: licht.de/Erco, photographer: Frieder Blickle)



## The Cologne Cathedral refurbishment

the previous metal halide lamps were replaced by controllable LED exterior lighting in 2025. The Gothic cathedral is illuminated by around 700 light sources. The lighting is dimmable and its colour temperature can be varied. Building-mounted LEDs deliver precise, pinpoint architectural highlighting with a significant reduction in stray light. The lighting control system also allows certain parts of the structure to be emphasised, and there is a night mode with lower lighting intensity.

[46] The new exterior lighting of Cologne Cathedral accentuates its architecture. (© Hohe Domkirche zu Köln, Dombauhütte, Photo: RheinEnergie AG, Luca Menke)



[47] Prior to the renovation, floodlights aimed at the cathedral emitted significantly more spill light. (Photo: licht.de/Signify)

Dynamic façade lighting often requires rapid colour changes and/or many individually addressable luminaires. This is where the DALI system reaches its limits. In this case, DMX controllers represent a good choice. However, dynamic lighting is not permitted everywhere, especially in the

vicinity of roads, where it may compromise road safety. City and local authorities regulate this on an individual basis with varying levels of stringency.



[48-50] Lens optics optimized for coloured LEDs ensure consistent colour mixing, soft transitions, and maximum efficiency for this sports and leisure site. (Photos: licht.de/WE-EF, photographer: Frieder Blickle)



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## Light management systems for streets and paths

In municipal lighting, a light management system can help to fulfil the legal energy-saving requirements without having to compromise on lighting comfort. Future-proof luminaires with standardised interfaces are the best means of achieving this. Various systems are available to choose from.

### **Self-contained sensor-based systems without cloud connectivity**

Self-contained solutions are a simple way of using light management in public spaces. Sensor-based systems allow the lighting to be activated as required. The sensor system can recognise road users and control groups of lights via a wireless connection. When no presence is detected, the lighting remains in sleep mode to save energy and reduce light pollution. This type of light management is recommended for near-natural cycle paths and footpaths, residential areas and car parks.

The limitations of these self-contained solutions are: Any adjustments to the light or sensor settings must be made locally, and the systems provide no feedback regarding luminaire failures. To overcome this, the systems can also be connected to an internet-based lighting control system.

### **Cloud-based light management systems**

Modern, cloud-based light management systems with remote connectivity serve as tools for municipalities and operators to streamline internal processes and asset

[51] With a controller, existing light points can also be easily connected to a networked management system. (Photo: licht.de/Signify)



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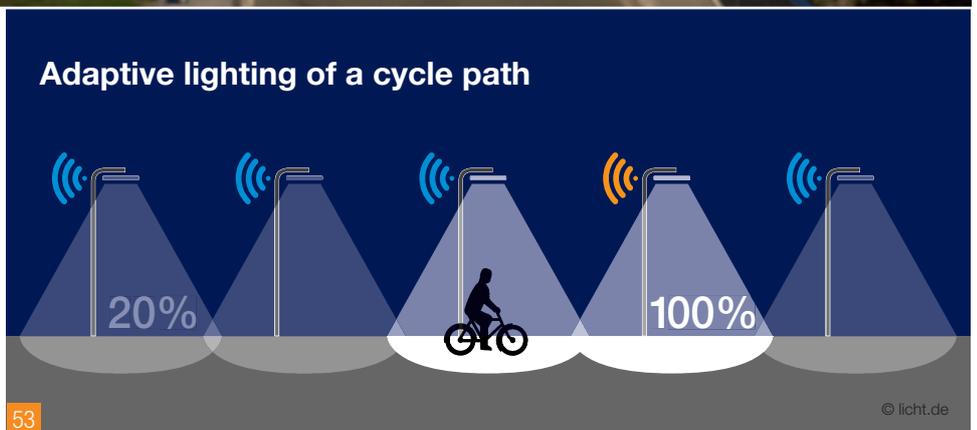
### Adaptive lighting of a cycle path

management. They enable the authorities to react flexibly and effectively to changing conditions (such as policy, energy costs and technology), making them essential to current operational processes. In light of the Cyber Resilience Act (CRA), manufacturers and operators are striving to ensure the highest possible level of security.

Fundamentally, a technical distinction is made between group control systems (feeder pillar control) and individual light point control systems. Both types feature a bidirectional communication link for data exchange, usually via cellular networks, and can be combined within the same light management software. Open interfaces for connecting third-party systems (APIs) – for integration into a data platform, for instance – enable municipalities to turn themselves into smart cities.

#### Group control in the control cabinet

Existing control cabinets equipped with photocells or ripple control receivers can

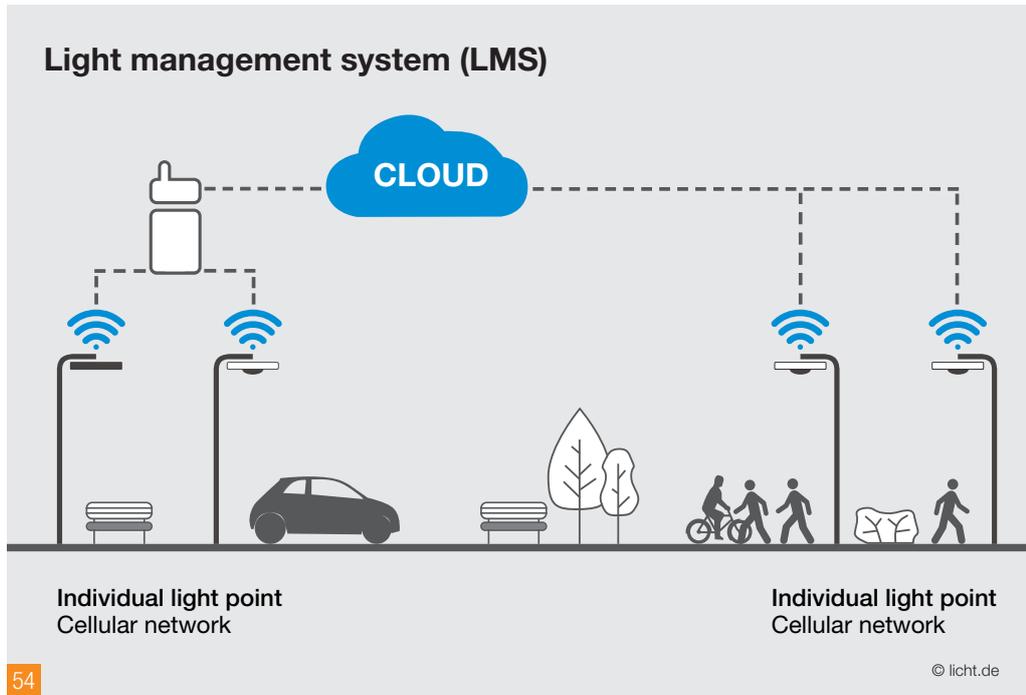


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[52] Adaptive lighting is made possible by luminaires fitted with sensors that recognise cyclists. When required, they regulate the lighting to full power; once the cyclists move away, the brightness is lowered again. (Photo: licht.de/Signify)

[53] Example of demand-based lighting control using autonomous sensors (© licht.de)



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now be retrofitted with modern controllers featuring bidirectional communication. Control units installed in the control cabinet allow for the separate switching and monitoring of the connected lighting circuits. Calendars stored in the light management system manage the switching times and can be adjusted as required. Possible additional functions include the integration of electricity meters, time-controlled night-time dimming and the monitoring of leakage currents or individual luminaire failures.

Group control is one of the simplest and most cost-effective solutions as a replacement for ripple control systems. The disadvantage is their lack of individual control and monitoring for each specific luminaire.

#### Individual light point control

Individual light point control is the preferred choice for both refurbishment and new-build installations. Each luminaire is equipped with a control node, which is typically connected via a Zhaga interface and automatically establishes a connection to the light management system. Integrated GPS modules in the control node transmit the position data of the luminaires and automatically display it in the light management system.

Technically, there are two main variants of **individual light point control**:

#### a) Direct cellular connection per controller

b) **Controllers that establish a local wireless network** that is connected to the cloud via central segment controllers.

Systems with a **direct cellular connection** can be installed on a 'plug and play' basis.. They offer the greatest planning freedom. A typical application for an individual light point control system with direct cellular connection is the monitoring of luminaires at pedestrian crossings distributed across the municipal or urban area. Luminaire failures are automatically reported to the light management system. The system operator can promptly rectify any defects and document them.

**Light management systems using local radio networks** offer advantages for large-scale, interconnected renovation projects. They deliver potential cost advantages; however, their planning and coordinated commissioning are more complex.



licht.wissen 03 provides information on lighting for streets, paths and squares



DIN 13201-1 is the German section of the EN 'Road Lighting' standard. 'Part 1: Selection of lighting classes' does not apply EU-wide.

[54] Illustration of an individual light point control system with a local RF mesh network and direct cellular connectivity in the control node (© licht.de)

[55] Open interfaces allow sensors to be connected to a light management system. The system automatically adjusts the lighting intensity in response to external influences. (Photo: licht.de/Signify)





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## Multi-storey car parks, car parks and forecourts

Entrances and exits to underground and multi-storey car parks are accident blackspots. Good lighting with no dark zones reduces the risk of accidents and facilitates orientation as well as the detection of vehicles, people, and obstacles.

For multi-storey car parks, DIN 67528 stipulates average horizontal illuminance of at least 300 lux at entrances and exits during the day, while 50 lux is sufficient at night. The reason is that during the day, the human eye only adjusts with a time delay from the bright surroundings to the comparatively dark entrance zones of multi-storey or underground car parks (adaptation). It can take minutes to adapt from light to dark, but only seconds in the reverse direction. Light management systems in combination with daylight sensors can compensate for this. Barriers may also

need to be illuminated. Average vertical illuminance of 50 lux is also prescribed for the car park itself at night. In certain parking spaces – such as those reserved for women, disabled persons and families – a higher level of illuminance will increase the feeling of safety. Light management systems which can address individual luminaires are most appropriate here.

Lighting control in conjunction with sensors can save a lot of energy in car parks. The basic light level can be significantly reduced, with the respective detection

[56] Uniform lighting with pleasant illuminance levels increases safety in parking facilities. (Photo: licht.de/Trilux)



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zone being adapted upon presence and motion detection. Furthermore, the surrounding area is not disturbed by excessive brightness at night. For parking facilities, the car park regulations of the federal states must also be observed, as well as DIN EN 12464 Parts 1 and 2 for workplaces.

#### **Parking spaces for women, families and people with disabilities**

The German Highway Code also requires women's parking bays to be well lit, video-monitored if possible, and located near exits, lifts or escape routes. Parking bays for people with disabilities and for families with small children are wider than standard spaces to allow car doors to be opened to their full radius. For this reason, luminaires in these areas must be positioned or aligned differently. These parking bays should also be positioned as conveniently as possible to ensure that

individuals with mobility impairments or respiratory illnesses only have to cover short distances

#### **Outdoor car parks**

Light management systems for outdoor lighting also raise efficiency levels and can be used to create interesting lighting effects. They control the brightness levels and switch off individual groups of luminaires completely when pathways and parking areas are not in use at night. It is recommended to combine motion detectors with light sensors to prevent outdoor lighting from switching on during daylight hours. Reducing the number of switching cycles also extends the lifespan of the luminaires.

Car parks are circulation areas. They are used by pedestrians, cars, motorbikes and bicycles alike. The risk of collisions increases along with the volume of traffic. Traffic volumes have an influence on the

required average illuminance levels. Light management and sensors can be adjusted to the required illuminance levels based on traffic volume. Depending on the user group, the values must comply with DIN EN 12464-2 (workplaces) or DIN EN 13201 (public areas).

[57] Sustainable and resource-efficient lighting for building exteriors is in high demand today: from car parks, paths, and entrance areas to site roads, storage, and logistics zones. (Photo: licht.de/Trilux)



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# Loading and storage

Warehouses consist of various areas: loading ramps, racking and offices all have different lighting demands. During the planning stage, high roof structures with significant light-mounting heights and often narrow racking aisles must also be taken into account. There is little or no daylight in many warehouses.

## Logistics centres and loading bays

Service yards are often used for the loading of goods. Outdoor lighting conditions are generally more challenging than indoors, where reflections from light-coloured walls provide additional brightness to the field of vision. Outdoor workplaces should be evenly lit. For this purpose, high-output luminaires are usually mounted on tall masts. Dangerous shadow zones must be prevented through effective lighting design. In view of the high energy costs, lighting should only be provided to the extent and in the locations required for loading and unloading operations.

The entrances and exits of logistics centres and warehouses also present a heightened accident risk. For example, moving from a brightly lit hall to a dark outdoor loading zone creates a hazard; a forklift operator may not detect personnel or obstacles, leading to potential collisions. Proper illuminance at entry points prevents such occurrences. DIN EN 12464-2 must be observed in areas where goods are loaded and unloaded. Light management systems equipped with sensors adapt the lighting to the respective pedestrian and vehicle traffic and address the luminaires individually.

## Glare-free lighting for stairs, ramps, and walkways

Outdoor stairs, ramps, and walkways should always be illuminated in such a way that the light shines directly onto the ground. Depending on the length of the walkways, a light management system can be useful for saving energy and improving safety in these areas. The combination of lighting systems with occupancy and motion sensors provides clear and safe illumination guidance. At the same time, the environment is not subjected to unnecessary stray light pollution.

Loading ramps are designed to facilitate the loading and unloading of transport vehicles. Lighting systems that simplify manoeuvring and direct truck traffic should be installed here to ensure smooth and safe operations. Targeted lighting with luminaires that are operated flexibly via a light management system equipped with motion sensors avoids stray light at night and protects the environment.

## Motion-controlled lighting for warehouse and racking areas

Safety in storage and racking aisles is increased through the use of lighting systems with integrated light management and presence/motion sensor technology. It drastically reduces energy costs by minimising the lighting level in areas where there is no movement and increasing it as required in areas where people and vehicles are in motion. A minimum amount of light is enough in fully automated, robot-operated warehouse areas. Basic, low-level lighting will extend the service life of the system. The light management system also enables the segmentation of zones and the assignment of fixtures or groups through individual addressing, ensuring that warehouse layouts can be used flexibly. Depending on the system's design and user requirements, the lighting can also be manually operated via push-buttons or control interfaces.

## Lighting for picking areas

As a rule, picking areas are used at different times of the day and for varying lengths of time. The range of visual tasks can also differ. At times of low occupancy, the illuminance is reduced to a minimum. A light management system with presence and, if required, daylight sensors provides an optimal solution here as well. It can help avoid unnecessary energy consumption, save money and reduce carbon emissions.

[58] For the sake of the environment, the upward light output of external luminaires must be restricted to prevent light pollution. (Photo: licht.de/Ledvance)

[59] Loading bays are integrated into buildings, forming a single functional unit with the doors and dock levellers. It can be dangerous for employees here, so good lighting is essential. (Photo: licht.de/Trilux)

[60] The intensity of individual lights or entire groups of lights can be adjusted via an app. (Photo: licht.de/Signify)



# Lighting control for indoor and outdoor sports facilities

In indoor and outdoor sports facilities, physical performance, the joy of the game, and spectator enjoyment are the top priorities. The lighting must therefore fulfil specific requirements. The focus is on visual tasks, brightness, lighting quality and technical designs that ensure durability and cost-effectiveness. Ecological aspects are also gaining in importance in the lighting of sports facilities.

Two aspects are crucial for meeting the diverse needs of sports hall users: firstly, the quality of light (horizontal and vertical illuminance, homogeneity, absence of glare and colour rendering ( $R_a > 90$ )); secondly, the lighting must be flexibly controllable.

## **Illuminance**

According to DIN EN 12193, there are varying requirements for horizontal illuminance depending on the type of sport and the lighting class. The recommended values for illuminance typically increase significantly for competitions and competitive training. For example, 300 lux is required for recreational table tennis, and 500 to 750 lux for competitions and competitive training.

If school sports halls are also used for community sports, they must also comply with DIN EN 12193. In addition, school sports are subject to the technical rules of ASR A3.4 and the lighting guidelines issued by the AMEV (the Working Group for Mechanical and Electrical Engineering of State and Local Administrations). These stipulate at least 300 lux.

## **Selection of luminaires and light management**

Today's light management options make it possible to operate sports facilities on an economically sustainable basis. Full lighting is only provided in areas where it is actually required. Separate settings can be made for individual zones within sports halls. Various pre-programmed light scenes are also possible for training and competitions. Digital, addressable lighting interfaces such as DALI open up a wide range of possible solutions. Where natural light is available in the hall, daylight sen-

sors can account for this influx when regulating illuminance levels. For the sporting activities themselves, such natural light is generally undesirable – it is, however, ideal for access routes into the foyer and other ancillary rooms. Presence detectors are effective at preventing light from being switched on in unoccupied areas. For car parks or park pathways, astro-timers or real-time clocks with programmed schedules can be used to track the local sunset.

## **Versatile use of multi-purpose halls**

Different types of sport require individual illuminance levels tailored to their specific needs (see table on page 58). This places high demands on the lighting itself and the uniformity of illuminance. The key to versatile room utilisation is an intelligent lighting management system. It adjusts the lighting level for the sport concerned and saves energy in the process. Programmed lighting scenes are accessible at the push of a button, e.g. for simple sports lessons or for competition matches.

In partitionable halls, or those where a stage can be installed, it must be possible to switch and dim the lighting separately for individual areas. Light management systems enable zoning through the programming of different luminaire groups and recallable scenes. Other uses are also conceivable – for example, for school events. The lighting is pre-programmed via a touch display or an app. These should be intuitive to operate.

## **Changing rooms**

Changing rooms require bright, uniform lighting. Stark shadows are unflattering. At the washbasins, mirror lights provide pleasant illumination of the face. High

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



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### Extract of requirements from DIN EN 12193 for community sports

Lighting Class III values for ten popular sports: training, physical education, and recreational use

Indoor system	Horizontal illuminance			
	$E_{hor Ave}$ lx	$U2_{hor}$	$R_{G^b}$	$R_a$
Ice hockey/figure skating* PA	300	70	40	60
Football, handball, karate, athletics, horse riding, shooting, gymnastics, swimming competitions*	200	0,50	40	60
Tennis				
PA	300	0,50	40	60
TA	75 % PA	75 % PA		

\* Starting and turning blocks  $E_{hor Min}$  lx 600  
 PA principal area  
 TA total area  
 Further values can be found in the standard.

vertical illuminance levels also help users see inside the lockers. Good colour rendering of light sources is beneficial to ensure that clothing colours are represented accurately. The advantages of light management systems in changing rooms and sanitary facilities include: enhanced safety, a longer service life for light sources, and optimum energy efficiency. The addition of presence and motion detectors allows the light to be dimmed or switched on and off as required.

#### Sports fields and outdoor facilities

Lighting for outdoor sports facilities is provided in most cases by high-power floodlights mounted on masts. The lighting task is best fulfilled by positioning the masts at the corners, or along the sides, of the playing field. Glare-free and uniform illumination of the playing field is achieved by mounting the luminaires as high as possible. To prevent stark shadows and avoid dazzling the spectators, the floodlights or spotlights need to be arranged so that all points on the playing field are illuminated from at least two directions. Light spill into the surrounding natural environment is undesirable for the protection of species, while in residential areas, consideration must be given to local resi-

[62+63] Floodlights make it possible to train even after dark. (Photos: licht.de/Signify)



dents. Effective lighting for sports facilities depends on the thorough, forward-thinking expertise of a professional lighting designer.



licht.wissen 02 'Learning in a New Light' also devotes a separate chapter to indoor and outdoor sports facilities.

# Sustainability and energy efficiency in the regulatory spotlight

Energy efficiency, sustainability and the circular economy are politically desirable and therefore enshrined in law. The European Union has a clear goal here: its Green Deal seeks to reduce net greenhouse gas emissions to zero and make Europe the first continent to become climate-neutral by 2050.

Companies draw up sustainability reports which document that their investments and actions fulfil at least one of the six EU environmental goals:

- 1) Climate protection
- 2) Adaptation to climate change
- 3) Sustainable use of water resources
- 4) Transformation to a circular economy
- 5) Prevention of pollution and protection of ecosystems
- 6) Biodiversity

The European Sustainability Reporting Standards (ESRSs) are also intended to contribute to achieving climate neutrality. They form a standardised reporting framework for environment, social and governance (ESG) issues in the EU. Modern lighting technology is sustainable and therefore a key factor in the transparent communication of ESG criteria.

## Environmental Product Declaration (EPD)

The Environmental Product Declaration (EPD) is a verified document that summarises the environmental impact of a product's life cycle. The results of a life cycle assessment can be presented in an EPD.

The growing demand for environmental product declarations is driving local initiatives worldwide to concretise the requirements for life cycle analyses and EPDs for lighting products through Product Category Rules (PCRs). The International Electrotechnical Commission (IEC) has initiated international standardisation for calculating EPDs. It is based on the 0014 Product Specific Rules (PSRs) for luminaires of the French environmental protection organisation PEP Ecopassport (PEP = Product Environmental Profile).

EPDs are based on the Life Cycle Assessment (LCA) methodology and thus provide a quantitative basis for comparing the environmental impact of products and services. They are prepared in accordance with the following standards:

- For the construction industry: DIN EN ISO 14025 and DIN EN 15804
- For the electronics industry: DIN EN ISO 14025 (Type III environmental declaration) and DIN EN ISO 14040/44 (Life cycle assessment); programmes such as PEP Ecopassport are based on these standards.

## Demand for renovation following the phase-out of conventional lamps

Conventional light sources are now history. Here, the EU legislation pursued a twin-pronged approach: the Ecodesign Regulation banned inefficient products, while the EU Directive 2011/65/EU on the restriction of hazardous substances in electrical and electronic equipment (RoHS) largely revoked the exemptions for the use of mercury in discharge lamps.

This has created pressure to modernise. Once the lamps used for years are no longer available, the entire lighting can be re-evaluated and a new lighting concept incorporating light management can be implemented.



The ZVEI has published a white paper entitled 'Upgrading of Luminaires'.

## Building Energy Act (GEG)

The Building Energy Act (GEG) is the German implementation of European Directive 2010/31/EU EPBD (Energy Performance of Buildings Directive) and the



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successor to the EnEV. Since 2020, it has been paving the way for efficient lighting systems with modern light management.

The previously parallel provisions of the German Energy Saving Act (EnEG), the Energy Saving Ordinance (EnEV) and the Renewable Energies Heat Act (EEWärmeG) were merged into a single set of regulations to create the GEG. It lays down requirements for the technology to be used in luminaires and control systems in non-residential buildings. In a calculation model, the energy consumption of the planned new building is compared with that of a reference building. The calculation is used to determine the primary energy demand (in accordance with DIN V 18599 'Energy efficiency of buildings – Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting') and is subsequently approved. DIN V

18599 from 2018 is the current applicable standard (see page 79). A valid energy performance certificate must be provided when selling or letting a building.

#### EU Buildings Directive EPBD

Buildings are the largest consumers of energy and, according to the German Federal Ministry for Housing, Urban Development and Building (BMWSB), account for around 40 per cent of the total energy requirement in Europe. According to the EU, around 85 per cent of all buildings were constructed before the year 2000 and 75 per cent of these exhibit poor energy efficiency. Renovation measures are therefore necessary to achieve the EU's energy and climate targets.

The new EU Energy Performance of Buildings Directive (EPBD) is intended to remedy this situation by setting minimum energy efficiency requirements. Lighting

[64] Regulations are adopted in Brussels which then have to be transposed into national law. (Photo: IMAGO/Chris Emil Janßen)

control systems also play a role in the EPBD. They represent optimum means of fulfilling the requirements of the directive on building and control systems.

#### EPBD 2024 version: Revision of the directive

In spring 2024, the EU published a revised version of the directive – with the aim of significantly reducing the carbon footprint of the building sector. At the same time, it promotes the use of intelligent, innovative technologies to improve indoor air and environmental quality. The updated directive stipulates minimum energy efficiency requirements for renovations and new builds of residential and non-residential buildings and includes a timetable for energy saving targets. These requirements must be transposed into national law in the EU member states by spring 2026 at the latest.

#### New EPBD requirements for building automation and control systems

Heating, space cooling, ventilation, domestic hot water and fixed lighting are classified as Technical Building Systems (TBS) and contribute to the energy consumption of a building. Systems that control and manage these functions are known as Building Automation and Control Systems (BACS). The revised EPBD contains specific requirements for controlling and reducing their energy consumption. A lighting control system for regulating fixed lighting is classified as BACS. This means that a building can utilise multiple BACS to manage different TBS functions – there does not have to be one single system for everything.

#### Requirements for BACS

Article 13 of the EPBD 2024 sets out specific criteria that EU Member States must take into account when defining national requirements to optimise the energy consumption of technical building services for existing and new non-residential buildings. Section 10 refers explicitly to building automation and control systems. They must be able to

- ,continuously monitor, record and analyse energy consumption and enable adjustment’.



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- ,assess the energy efficiency of the building, recognise efficiency losses in the technical building equipment and inform the person responsible for facility or technical building management about ways to increase efficiency’.
- ,communicate with connected technical systems and other devices in the building and be interoperable with various proprietary technologies, devices and manufacturers’.
- ,facilitate the monitoring of indoor air quality from 29 May 2026’.

Section 12 also describes the criteria and applications in which lighting controls are prescribed. Automatic light management systems must be zoned accordingly, have presence detection and be implemented by the following deadlines:

- by 2028 for non-residential buildings with an installed heating, cooling or ventilation capacity of more than 290 kilowatts

[65] Efficiency and sustainability in architecture: A smart building uses intelligent systems to conserve resources. (Photo: AdobeStock/axel)



- by 2030 for non-residential buildings with an installed heating, cooling or ventilation capacity of more than 70 kilowatts

#### Smart Readiness Indicator – how smart is a building?

The revised EPBD contains a new parameter to promote intelligent building technologies: the Smart Readiness Indicator (SRI). It assesses the extent to which a building is capable of

- optimising its energy efficiency and energy consumption,
- adapting its operations to the needs of users
- and reacting flexibly to signals from the energy grid.

It comprises a catalogue of ‘Smart Ready Services’ across nine technical domains. These include: heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, power supply, electric

vehicle charging infrastructure, as well as monitoring and control. Table 2.1 rates functions for ‘presence detection for indoor lighting’ on a scale of zero to three – ranging from non-smart to maximum smartness.

#### Functionality level

An SRI assessment required to grade a building’s lighting domain consists of evaluating the performance of the defined Smart Ready Services against the following seven targeted impact areas for smart buildings:

- Energy efficiency
- Maintenance and fault prediction
- Comfort
- Convenience
- Health, well-being and accessibility
- Information to occupants
- Energy flexibility and storage

The result of this assessment is expressed in a total SRI building value,

which reflects the extent to which Smart Ready Services have been implemented.

Each functionality level of a Smart Ready Service has its own individual ratings for the seven addressed impact criteria mentioned above, which are categorised in levels 0 to 3.

#### Lighting controls

The choice of lighting system in new and renovated buildings plays a key role – especially in reducing the carbon footprint and complying with EPBD requirements. LED luminaires with a lighting control system that automatically adjusts the lighting level based on presence or available daylight contribute significantly to energy savings and help to achieve sustainability goals.



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## Smart investment with high cost-effectiveness

Investing in an intelligent light management system saves operating costs in the long term. The initial additional costs compared to a non-controlled lighting system are often recouped within a short space of time. Beyond this point, additional energy savings effectively become profit. It is important to know the factors that determine the savings potential and thus the possible yield.

The cost-effectiveness of a lighting system and its control is determined by its benefits and costs. Expenditure is thus calculated over the entire life cycle:

- Acquisition and installation costs
- Capital costs (interest), if applicable
- Maintenance and repair costs
- Energy costs
- Costs for dismantling and disposal

These constitute the total costs of ownership (TCO) for the lighting, which is calculated over a defined reference period – not exceeding the useful life of the light management system. Light management is considered economically viable if the investment and capital costs can be offset by savings in maintenance and energy op-

erating costs – in other words, if the system has paid for itself before the end of the assessment period.

### Assessment period and payback period

The assessment period should be selected to align with the economic horizon of the end customer or the specific application. This is particularly true in the case of a project in rented premises. Then it is not the investor who benefits from the savings, but the tenant. To ensure a fair balance of interests here, model calculations should be used to ensure that both parties benefit from the savings.

Many investors are reluctant to set an assessment period of more than five years

[66] Lighting systems controlled via sensors minimise energy consumption, operating costs, and maintenance requirements. (Photo: AdobeStock/Ngampol)

because, in a rapidly changing world, they consider long-term projections to be unreliable. In this case an assessment period should be selected which is roughly 30 to 50 per cent longer than the payback period of the simplest lighting solution. This ensures that even investment-intensive solutions which offer greater savings (such as lighting control systems) can prove their efficiency and be implemented. As a general rule, the longer the assessment period, the more likely it is that optimised solutions can be selected.

Very long life cycles are characteristic for street lighting. An operating life of 25 years is a guideline value that is often exceeded by a significant margin. This is a good reason to base decisions regarding costs and expenses not only on the initial investment, but on the entire operating life.

Therefore, in most cases, focusing solely on the payback period is too narrow an approach. As a rule, it does not lead to the most economical solution (or decision). For a system which includes light management, the payback period may be longer due to the higher initial investment, however, the total return increases because of the greater savings over the assessment period. New lighting systems therefore

represent a very safe and sound use of funds.

### Energy costs – the primary driver

Energy costs constitute a major part of the operating costs. This is the most powerful lever for permanently reducing lighting costs – a convincing argument in favour of using energy-efficient lighting technology and demand-oriented lighting control. The price of energy in Germany also fluctuates in response to geopolitical uncertainties. Every kilowatt hour of electricity that is not consumed saves money. A light management system contributes to this with an average saving potential of 25 to 35 per cent.

### Operating hours

The operating hours are generally determined by calculating the working hours and the presence of staff at the workstation. Specific figures for this should, where possible, be determined in consultation with the operator. Valuable information on this, as well as on occupancy idle times that can be utilised through automated switching, can be found in DIN V 18599-10.

### Dimming

Many factors contribute to saving electricity through dimming, such as the size of

the windows, the geographical location and the orientation of the building. The potential for savings in the case of large window areas (daylight ingress) is considerable.

### Upfront costs

The higher upfront costs of a system with light management consist of:

- Device costs
- Additional costs for installation materials
- Labour costs for assembly
- Labour costs for commissioning

### Financing

Those who prefer not to pay for new lighting immediately or in full, can take advantage of grants or low-interest loans – or simply rent their lighting.



At the time of publication, the funding landscape in Germany was undergoing significant upheaval. The industry initiative licht.de therefore publishes information regarding current programmes on its German website.

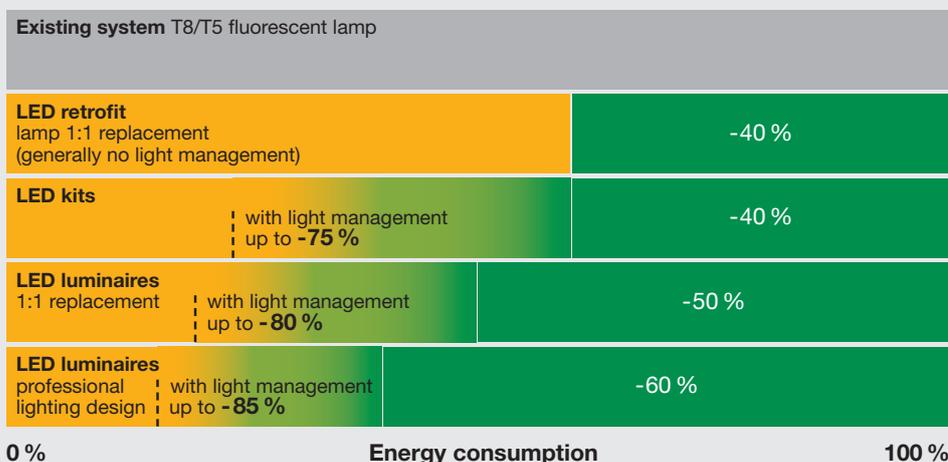
### Maintenance

Maintenance costs must be calculated separately. Additional costs for maintenance are generally offset by a longer service life. The savings are often even greater, for example due to centralised fault reporting or the extended service life of the lamps (see page 24).

### Service life

The entire useful life of the system is the relevant factor for determining the service life. It also depends on the use of the building. While industrial companies often plan for decades, service lives of five to seven years are usual in shopfitting.

## Energy-saving potential of LED lighting



Typical savings achieved through LED technology: Additional savings potential through light management depends on occupancy patterns, daylight availability, as well as the effectiveness of sensory detection and the implemented switching and dimming functions.

[67] Switching to energy-efficient LED luminaires combined with light management systems and professional lighting design can save up to 85 per cent of energy. (© licht.de)



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For longer investment horizons, longer payback periods are generally considered economically acceptable. In any case, when making an investment decision, it should be considered whether a supposedly cheaper solution actually maximises potential returns during the remaining service life after its payback period.

Luminaire manufacturers must provide information on the reduction in luminous flux in relation to the service life. Any replacement investments that arise must also be factored into the analysis.

#### Total savings over the life cycle

An analysis of all costs over the entire life cycle reveals that systems with a higher initial investment and consequently a longer payback period can, in the long run, save even more costs than systems that pay for themselves faster. The payback period decision parameter therefore usually yields only the simplest alternative, and rarely the best and most attractive long-term solution. High-quality LED luminaires in con-

junction with a light management system are usually more expensive to procure, yet represent an attractive proposition in the long term due to the low life cycle costs thanks to their high efficiency and low maintenance costs. They also offer consistently higher light quality – an advantage in terms of people’s sense of well-being.

#### Lighting quality

Costs for subjective values such as ‘quality’ are difficult to calculate. Various studies have concluded, however, that better lighting quality has a direct impact on the users of the lighting.

Decision-makers are well advised to consider the relevant criteria for a lighting system in advance and to seek comprehensive advice from planners. In addition to the lighting quality of a system, other aspects should also be taken into account, such as product quality, long-term economic factors such as the service quality of the provider or the service life of the lighting system.

[68] Alignment with working hours, occupancy, and especially daylight opens up a wide range of opportunities for lighting energy savings. Light management systems perform this task effortlessly (photo: licht.de/Zumtobel, photographer Jens Ellensohn)

[69+70] In both indoor and outdoor lighting, light management systems help to reduce unnecessary energy consumption. (Photo: licht.de/Loblicht; ZVEI © OFB Projektentwicklung/photographer: Klaus Helbig)



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## Interfaces for building light management

Interfaces must be compatible to ensure that all technical components – from heating and air conditioning to lighting – can be connected to a single system and controlled from a central point. Wireless and wired solutions complement each other perfectly in the world of automation.

Interfaces must be compatible to ensure that all technical components – from heating and air conditioning to lighting – can be connected to a single system and controlled from a central point. Wireless and wired solutions complement each other perfectly in the world of automation.

Interfaces allow different components in the light management system to communi-

cate with each other. All relevant information is collected in the control unit and transmitted to the components as required. There are interfaces between the control unit and the users, sensors and the control gear of the luminaires.

Fundamentally, a distinction must be made between two levels of interfaces in lighting technology:

## Overview of connection options

	Possibilities	Principle	Operation	Group reconfiguration
Switching	<ul style="list-style-type: none"> <li>Activation based on presence or motion</li> </ul>	Sensor	Local	Rewiring
1...10V	<ul style="list-style-type: none"> <li>ON/OFF via mains switch</li> <li>Stepless dimming for all dimmable light sources</li> </ul>	2-wire BUS, analogue, stand-by		
DALI	<ul style="list-style-type: none"> <li>ON/OFF</li> <li>Stepless dimming for all dimmable light sources, colour control, light scene programming</li> <li>Can be combined with time control</li> </ul>	2-wire BUS, digital, stand-by	Local & centralised	Programming
DMX	<ul style="list-style-type: none"> <li>ON/OFF</li> <li>Stepless dimming for all dimmable light sources, colour control, light scene programming, rapid sequence switching supported</li> <li>Can be combined with time control</li> </ul>	Multiplex, digital control protocol (from stage lighting), stand-by		
Zigbee	<ul style="list-style-type: none"> <li>ON/OFF</li> <li>Stepless dimming for all dimmable light sources, colour control, light scene programming</li> <li>Can be combined with time control</li> </ul>	Wireless, stand-by		
EnOcean				
Bluetooth				
Wi-Fi				
Network interfaces (e.g. BACNET, LON, KNX, manufacturer-specific networks, Ethernet-TCP/IP/computer network)		Wired		

■ **Lighting interfaces** enable the user to directly connect control components and luminaires that share the same interface. Their functions are standardised in relation to lighting control.

■ **General data interfaces** are used within a control system. These interfaces, too, are mostly standardised, though only with regard to the data exchange between transmitter and receiver. Their functions in relation to lighting control are defined by the manufacturer.

A distinction can also be made between wired (such as DALI) and wireless interfaces. The complexity of the system is determined by the number of interfaces and functionality requirements.

Popular standards for wireless communication are Zigbee, EnOcean, Bluetooth, Matter and Thread (see pages 78-81).

Connectivity via Bluetooth and Wi-Fi enables intelligent control through mobile devices and apps (Smart Home), with lighting continuing to play a key role in the Internet of Things (IoT). It subtly supports people in their activities.

[71] Interfaces connect components such as control units, sensors and lights – or even entire smart cities. (Photo: Adobe-Stock/metamorworks)

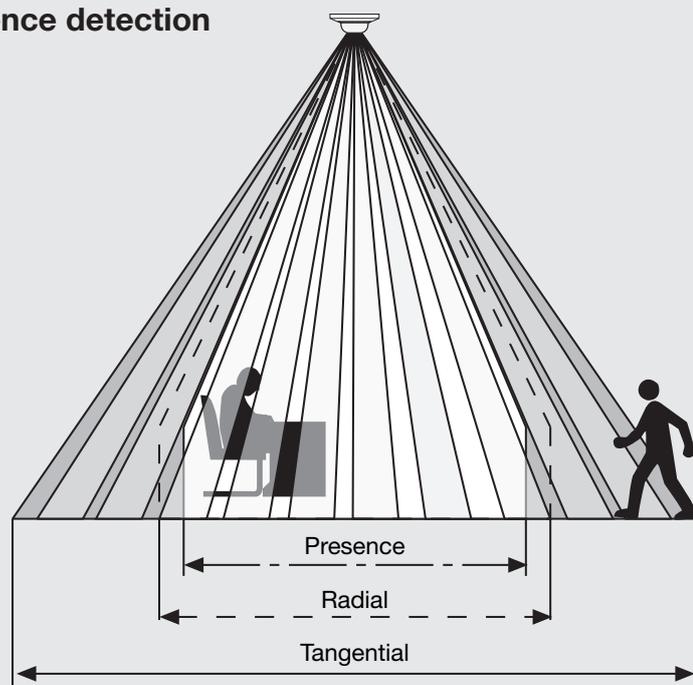


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[72] The task of light sensors is to measure the incident daylight. A special brightness sensor is mounted in addition to the luminaire for this purpose. (Photo: licht.de/Molto Luce)

[73] Passive infrared (PIR – see page 73) sensors detect heat radiation from moving people and vehicles, for example. Moving bodies are registered as changes in voltage. High-frequency (HF) sensors actively scan their detection area. (© licht.de)

### Presence detection



#### Tangential detection

Transverse detection indicates the distance from which a movement transverse to the sensor is detected.

#### Radial detection

Frontal detection indicates the distance from which a movement directly towards the sensor is detected.

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# Sensors – the basis of effective light management

Light management projects are always individual and often complex. There are suitable sensors for every stage of expansion – ranging from basic motion and presence detection to daylight-dependent control for interiors, or lighting control based on traffic volume and weather conditions for street lighting. They continuously measure the relevant parameters and enable automatic adjustment of the lighting according to the specified set values.

## Sensors for daylight harvesting

‘Smart’ lighting management utilises natural light, offers high levels of comfort, and provides the greatest potential for energy savings. Light sensors measure the amount of incident daylight on a reference surface in a building. If the illuminance level falls below a pre-set target value, artificial light is switched on as required or continuously adjusted via stepless control. Daylight varies according to the time of day and season, as well as weather conditions and geographical location. Due to these fluctuations and depending on the room depth, it is often impossible to dispense with artificial lighting even during the day – for example, to meet legal and normative requirements (such as ASR A3.4 and DIN EN 12464-1).

## Sensors for motion and presence detection

Motion sensors detect and respond to walking and driving movements within their detection zone. A typical example is a residential motion detector: it detects people in the dark and switches the light on automatically. The light is switched off again after a predefined period without motion. Integrated twilight switches ensure that motion detectors only operate during the hours of darkness.

Presence sensors are more sensitive than motion sensors. They react to even the smallest movements, for example when a person is working at a desk. Their task is to reliably switch off or dim the light in an office or corridor, for example, when the

room is unoccupied. If presence and activity are detected, the lighting is switched on again or ramped up to the desired brightness level. All presence sensors are also motion sensors, but not every motion sensor is a presence sensor.

Presence and motion sensors are often combined with light sensors to enable daylight-dependent lighting control.

## Daylight measurement: The basis for lighting control and regulation

There are two technologies to choose from for the demand-based control of artificial lighting:

- In the case of **light control**, the daylight is measured at a suitable point and the artificial lighting is dimmed and switched on or off based on the amount of daylight.
- With **light regulation**, the desired illuminance is set in advance. This ensures a constant level of illuminance – even deep within the room and regardless of the time of day or season (= constant light regulation). The system measures the total current light levels in the room (= the sum of daylight and artificial light) – and automatically regulates the artificial light to the predefined illuminance level.

In combination with motion and presence sensors, the luminaires in both cases are only switched on when movement is detected and when ambient light levels are low.



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### Three types of daylight sensors

#### Internal look-down sensors

Mounted at the workstation. Detect the light directly beneath the sensor:

- + Measure the light where it is needed and continuously adjust it to keep it constant.
- + Maintenance factor compensation for individual luminaires
- Risk of mutual interference
- Heavy dependence on the reflective surface

#### Internal look-out sensors

Mounted at the workstation. Capture the incident light at one point:

- + One sensor can control several rooms of the same type.
- Do not detect shading in the room

#### External daylight sensors

Installation of a sensing head centrally on the roof. Records external daylight conditions:

- + The light quality (position of the sun, diffuse/directional, etc.) can be recorded via additional components.
- + Cost-effective for large buildings
- No information regarding the building interior



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### Sensors for presence detection

Two sensor technologies can be used to fulfil all standard requirements for motion and presence detection:

- 1) **Passive infrared (PIR) sensors** transmit a short signal as soon as they detect a change in temperature. A lens is used to divide a defined area into active and passive zones. If a physical body, for example a person, moves through multiple zones, its heat is registered in the form of infrared radiation. PIR sensors do not emit any radiation themselves (= passive) and can be used indoors and outdoors. Typical areas of application include offices, classrooms, corridors and outdoor areas surrounding a building.
- 2) **High-frequency (HF) sensors** scan their detection area (= active). Similarly to bats, signals are emitted and then received back as reflected echoes. A change in the echo signifies the detection of movement. HF sensors are suit-

able in situations when objects or people emit no infrared radiation (such as cold vehicles or people dressed warmly in winter) or if the sensor is to be installed in a closed luminaire. Typical areas of application include entrances, underground car parks, warehouses and traffic routes.

Luminaires can also provide the infrastructure for other sensors (air quality, temperature). The DALI BUS can pass on gathered information in DALI-2 systems (compare Parts 251 to 253 of the DALI standard, EPBD 2024 Article 13d, and Indoor Environmental Quality, IEQ).

[74] When installing sensors, factors such as mounting height, room size, detection geometry and climatic conditions must be taken into account to ensure smooth operation. (Photo: licht.de/Esylux)

[75] Light is a key factor in the design of modern workstations. It creates the conditions for good vision and a pleasant atmosphere. (Photo: licht.de/Signify)

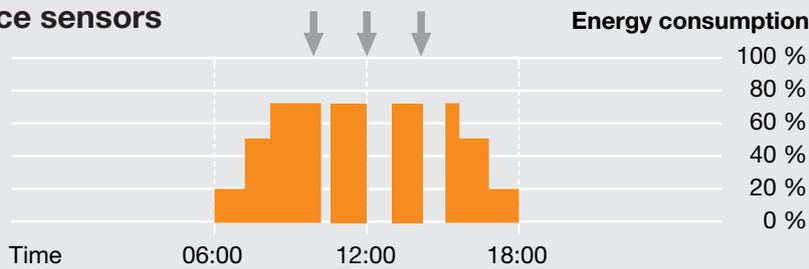
## Presence and motion detector technologies

Detector	Used in	Applications	Advantages	Disadvantages
PIR	<ul style="list-style-type: none"> <li>Presence and motion detectors installed separately or integrated into luminaires</li> <li>Mostly used in conjunction with daylight sensors</li> </ul>	<p>Main uses:</p> <p>Office areas, corridors, classrooms, communal areas, entrance areas</p>	<ul style="list-style-type: none"> <li>Simple installation of the detector</li> <li>Easy commissioning of the detector</li> <li>Cost-effective and therefore suitable for building-wide deployment</li> <li>PIR = Passive infrared: The detector emits no active signals that could negatively impact the environment.</li> <li>Easily restrictable detection area</li> </ul>	<ul style="list-style-type: none"> <li>Susceptible to interference from moving air (e.g. from fans)</li> <li>Only moving bodies emitting heat radiation are detected. This means no detection through walls or of non-moving bodies emitting no heat radiation.</li> <li>When installed in a luminaire, the lens of the PIR must always be visible and cannot be integrated invisibly behind a cover.</li> </ul>
High frequency/radar	<ul style="list-style-type: none"> <li>Presence and motion detectors installed separately or integrated into luminaires</li> <li>Partly used in conjunction with daylight sensors</li> </ul>	<p>Main uses:</p> <p>Underground car parks, industrial applications (especially with heat sources, large ventilation systems)</p>	<ul style="list-style-type: none"> <li>Simple installation of the detector</li> <li>Easy commissioning of the detector</li> <li>Cost-effective and therefore suitable for building-wide deployment</li> <li>When installed in a luminaire, the detector can be integrated invisibly behind a cover.</li> </ul>	<ul style="list-style-type: none"> <li>Poorly defined orientation, making it prone to interference (e.g. detection through walls)</li> <li>Active high-frequency signals are constantly emitted by the detector</li> </ul>
Optics/ Camera (OCR chip)	<ul style="list-style-type: none"> <li>Special detectors which are usually installed individually in selected rooms.</li> </ul>	<p>Main uses:</p> <p>Detection of room boundaries and person counting in indoor spaces (e.g. meeting rooms, event venues)</p>	<ul style="list-style-type: none"> <li>Optimum detection through digital evaluation of optical signals</li> <li>Detection almost error-free</li> <li>Simple installation of the detector</li> <li>Often requires no additional daylight sensors, as light levels can be measured via optical sensing.</li> </ul>	<ul style="list-style-type: none"> <li>Commissioning is work-intensive due to the use and parameterisation of special software</li> <li>Relatively cost-intensive compared to detectors with alternative sensor technology, therefore not suitable for widespread use</li> </ul>
Acoustic	<ul style="list-style-type: none"> <li>Used in buildings almost exclusively in combination with PIR sensors, but occasionally with high-frequency sensors</li> <li>Presence and motion detectors installed separately or integrated into luminaires</li> </ul>	<p>Main uses:</p> <p>L-shaped or partitioned rooms where occupants are stationary or move very little (e.g. toilets/washrooms)</p>	<ul style="list-style-type: none"> <li>Large detection area</li> <li>Simple installation of the detector</li> <li>Easy commissioning of the detector</li> </ul>	<ul style="list-style-type: none"> <li>Susceptible to interference from external noise</li> <li>Impossible to delimit the detection area</li> </ul>
Temperature, VOC, humidity, CO <sub>2</sub> etc.	<ul style="list-style-type: none"> <li>Used in buildings almost exclusively in combination with PIR sensors and high-frequency sensors</li> <li>Only useful in buildings that use a BUS system (KNX, DALI-2) and software that can analyse the data collected by the sensors</li> </ul>	<p>Main uses:</p> <p>Rooms where, in addition to detecting the presence of people to switch or control the lighting, further environmental parameters are to be recorded, such as room temperature, air quality, and humidity.</p>	<ul style="list-style-type: none"> <li>Simple installation of the detector</li> <li>The infrastructure required primarily for light management is also used to detect other room parameters.</li> </ul>	<ul style="list-style-type: none"> <li>Commissioning is relatively complex</li> <li>For correct operation, these detectors require a certain level of air circulation; consequently, integrating them directly into luminaires is a high-effort process.</li> </ul>

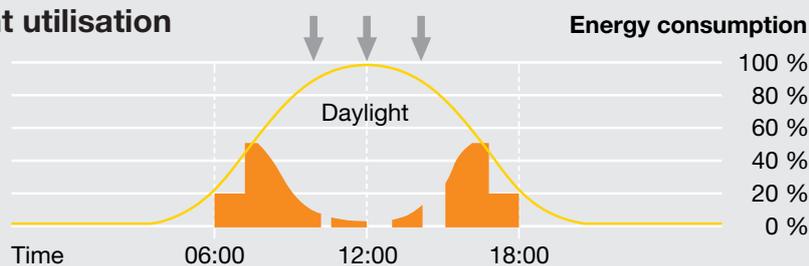


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### Presence sensors



### Daylight utilisation

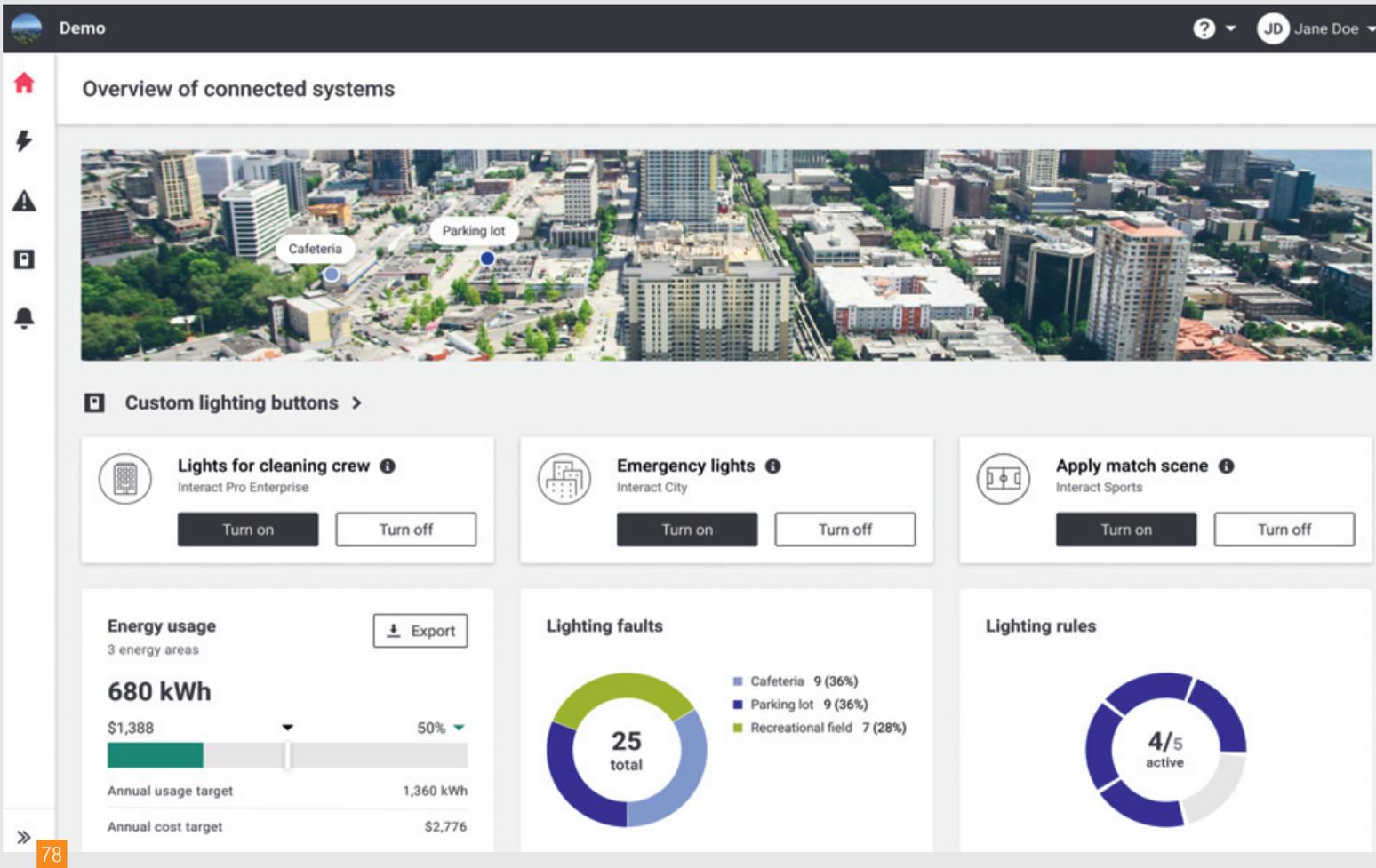


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[76] Motion detectors recognise larger movements within their detection area, such as a person walking through a corridor. They then perform a one-time light-level measurement using their integrated sensors. If it is below the pre-set brightness threshold, the lighting is activated. If they no longer detect any movement, they switch the light off again once the run-on time has elapsed. ([licht.de/Esylux](http://licht.de/Esylux))

[77] Daylight and presence detection helps educational institutions to save a lot of energy and reduce operating costs. The [licht.de](http://licht.de) chart shows energy consumption at the time of use. (© licht.de)



# Software

Lighting control plays a central role in modern building technology. Software solutions enable lighting designers and system integrators to design lighting efficiently and flexibly. This chapter presents different types of software used for lighting control. From commissioning software, user interfaces and monitoring software to mobile applications and software development kits – each of these solutions helps to optimise the control and monitoring of lighting systems. The aim is to provide lighting and electrical planners or other specialised personnel with a readily comprehensible overview of the software tools available and to explain their benefits for their daily work.

## Commissioning software

Commissioning software for lighting control systems enables new lighting systems to be commissioned simply and efficiently. In many cases it includes a user-friendly interface that enables the lighting technician, installer or facility manager to configure and test various light sources and control components. Typical functions include automatic device recognition, the configuration of lighting groups and scenes and the integration of sensors and actuators. Using the commissioning software can shorten installation times and minimise installation errors.

## User interfaces

User interfaces for lighting control systems are designed to make the operation and management of lighting systems as intuitive as possible. They include web applications, desktop software or mobile applications and provide a visual representation of the lighting system. Authorised users can use these interfaces to configure light scenes, create schedules and adjust the brightness and colour temperature of technically compatible luminaires. Well-designed user interfaces facilitate the control and monitoring of the lighting, contributing to the system's efficiency and user-friendliness.

[78] Buildings or entire neighbourhoods – user interfaces provide a quick and intuitive overview.



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### Monitoring software

Monitoring software for lighting control systems enables the continuous supervision and analysis of lighting installations. The software collects data on energy consumption, hours of operation and the condition of the light sources. Facility managers can use the monitoring software to recognise problems at an early stage and plan maintenance accordingly. In addition, the software often includes functions for creating reports or dashboards and for visualising performance indicators, which all help to optimise the lighting and reduce energy costs.

### Apps for lighting control

Lighting control apps represent a flexible and mobile means of controlling lighting systems. These apps are available for smartphones and tablets and allow the user to control light sources locally and, if required, remotely. Typical functions include switching luminaires on and off, dimming, colour control and the creation of lighting moods. Some apps also offer the integration of other technical systems and the option of operating lighting con-

trols via voice commands. Apps allow users to adjust the lighting conveniently and efficiently to their needs.

### Software Development Kit (SDK)

A software development kit (SDK) for lighting control systems provides software developers with the tools and libraries needed to create custom applications that communicate seamlessly with the lighting hardware and software. An SDK typically includes APIs (Application Programming Interfaces), documentation and sample code, which facilitate the integration of lighting control functions into custom software solutions. Developers can use an SDK to implement specific requirements and functions, such as controlling DMX devices, synchronising light shows with music, or creating custom user interfaces. Companies can use an SDK to expand their lighting control systems and tailor them to their individual needs.

[79] Monitoring software for lighting systems records energy consumption and system status. It also enables fault detection and demand-based control. (Photo: licht.de/Waldmann)



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## Technical terms

### Analogue interface 1...10 V

An interface that has been in use for many years is the 1...10 V interface. In this case, the control gear acts as an active load and provides the control voltage. The luminous flux of the light varies with the level of the control voltage.

### API

Different programmes or systems can communicate with each other via an API (Application Programming Interface). It defines how software components interact with each other without the need to understand their internal workings. It shows which data is available and makes it possible to request functions or data. Web and REST APIs are used particularly frequently. They facilitate integration and collaboration between different programs and are a fundamental component of modern software development. Their independence from specific programming languages makes them flexible to use and easy to scale.

### BACnet

The building-level interface BACnet (Building Automation and Control Networks) seamlessly integrates lighting systems with other building functions, such as heating, ventilation, air conditioning (HVAC), security systems, and energy management. This facilitates communication between different devices. BACnet is suitable for both small and large installations and supports various network standards, enabling the expansion and customisation of light management systems.

### Bluetooth

Bluetooth is a standard technology for wireless communication and luminaire control. Its greatest advantage is that it offers direct control via mobile devices (smartphones, tablets). Mesh networks have now become established for this purpose because they can network larger lighting systems.

[80] Presentations, discussions, lectures: rooms for conferences and training courses are communication hubs, equipped with modern media technology. They are designed for multifunctional use and thus require flexible lighting that is both pleasant and effective. (ZVEI © OFB Projektentwicklung/photographer: Klaus Helbig)

## Building Management Systems (BMSs)

BMSs are computerised systems that are installed in buildings to control and monitor their mechanical and electrical systems, such as the heating, ventilation and air conditioning, lighting, energy, fire protection and security systems.

### Constant light control

In rooms where daylight enters through windows or skylights, the artificial lighting does not need to be switched on at its maximum level at all times. In such cases, constant light control is the ideal solution: a daylight-dependent system that combines natural light with regulated artificial light to maintain a consistent lighting level. With this type of constant light control, the illuminance remains consistent throughout by increasing or decreasing the artificial light as the daylight contribution varies. Accordingly, the lighting is reduced or switched off when there is plenty of light outside and increased when there is little daylight. NB: Workstations located deep within a room, far from the window front, should receive more artificial light from the installed luminaires than those in close proximity to the windows.

### Corridor function

The corridor function is a special setting for the efficient lighting of circulation areas. It ensures that the lights are only switched on in hallways or corridors when they are actually needed. This saves energy and extends the service life of the light sources.

The corridor function is typically activated by motion or presence detectors. When someone enters the corridor, the lighting switches on for a certain amount of time. After a set period without movement, it switches off again automatically. This approach is useful for public buildings, offices or residential complexes where corridors are frequently used but do not need to be illuminated all the time.

### DALI

DALI is a standardised interface in conformity with IEC 62386. All devices that are DALI-2 certified can be used interoperably in a project.

DALI is suitable for use in individual rooms, storeys and buildings and can also be integrated into a higher-level building management system. A distinction is made between two communication principles:

- **DALI broadcast (Direct DALI)** All devices respond to the control signal simultaneously.
- **DALI addressing mode** Each device is assigned an individual address and can optionally receive up to 16 group addresses and 16 scene settings.

For installers, the advantages over other interfaces include the simple, polarity-free connection of DALI participants, as well as the ability to route the control lines and the mains supply (230 V) within a single multi-core cable (such as 5-core NYM). This means that the entire room lighting can be controlled with just one gateway node.

In addition to the assignment of individual and group addresses and status queries, the DALI interface enables the transmission of numerous DALI parameters and commands from the controller to the control gear. The most important DALI parameter, used in all DALI applications, is the dimming level. It is transmitted with 8-bit resolution (255 steps from 0% to 100% and 'no change'). Further DALI parameters can be used for specific applications



Digital Alliance

### Daylight sensors

An external daylight sensor uses multiple sensors to determine the direction of the sun, sky conditions and the intensity of the daylight. The measuring head is mounted centrally on the roof.

### DIN V 18599

The pre-standard illustrates the influence that control and regulation – alongside room and building automation, including technical and energy-related building management – have on a building's energy requirements during operation. Energy management, as part of overarching building management, is of particular importance for energy-efficient building operation, coordinating the distribution and use of

energy within the building. DIN V 18599 is structured in several parts.

- **Part 4** enables the determination of net and final energy requirements for lighting. The calculations utilise statistically determined data for the energy efficiency of the technologies and lighting used.
- **Part 10** specifies the boundary conditions for use, such as operating hours or assumed absence for individual offices and a further 40 room types.
- **Teil 11** describes the energy management functions and their interactions with the other areas of energy use in the building.

### DMX 512

The DMX 512 standard was created for stage lighting back in the early 1990s in order to be able to control many devices quickly and individually by means of addressed digital control signals. The DMX interface is also often used in architectural lighting (see page 44). There is a wide variety of products available, especially for colour-changing luminaires.

### DMX RDM

The DMX signal is transmitted via a shielded, twisted-pair control cable. The further development of the DMX standard into DMX RDM enables feedback from the devices to the controller. Users particularly value the high flexibility and speed of this interface for implementing dynamic lighting control, as well as the large number of participants on a single control line.

### Energy Performance of Buildings Directive (EPBD)

Directive (EU) 2024/1275 on the energy performance of buildings (Energy Performance of Buildings Directive) is one of the EU's most important legal instruments for improving the energy performance of buildings, alongside the Energy Efficiency Directive. The original Directive 2010/31/EU was inspired by the Kyoto Protocol, which obliges the EU and all its members to set binding emission reduction targets. After being amended several times, the Directive was comprehensively revised in 2024.

### Enocean

Enocean technology requires only small amounts of energy to transmit brief radio signals. The transmitters therefore utilise the piezoelectricity of switches (energy harvesting), the energy of solar cells or Peltier elements, or the kinetic energy of electrodynamic energy converters. This provides sufficient energy for the battery-free and low-maintenance operation of the transmitters. In some applications, however, neither sufficient lighting nor mechanical actuation can be expected, meaning that batteries are sometimes used as a power source.

### Fully automatic

In the fully automatic operating mode of presence and motion detectors, the lighting is switched on when presence or motion is detected and the light level falls below the switching threshold or brightness setpoint. For detectors with a light control option, the control process is initiated.

If presence or motion is no longer detected, the run-on time begins, after which the light is switched off or the control process is terminated.

### Human Centric Lighting (HCL)

A light management system is a prerequisite for HCL lighting. HCL systems vary the colour temperature from warm white to daylight white over the course of a day. The illuminance is also adjusted to suit the human circadian rhythm, providing the right stimuli depending on the time of day. The individual luminaires are controlled seamlessly, ensuring that changes are not immediately perceptible, while allowing their non-visual effects to be fully realised over a longer period. Daylight determines the factors to be planned and controlled by the light management system: illuminance, uniformity, light direction, colour temperature, and the dynamics of light throughout the day and the seasons. For implementation of HCL concepts, the lighting and electrical industries provide a comprehensive portfolio of light management systems with suitable application software that can be integrated into building management systems if required. HCL concepts must be established at an

early stage of the project and form the basis of holistic, interdisciplinary planning.



Further information can be found in the following booklets: licht.wissen 19 'Impact of Light on Human Beings' and licht.wissen 21 'Guide to Human Centric Lighting (HCL)'.

### KNX

KNX is an intelligent BUS system for electrical installations. It networks all building services components and controls them intelligently – for example, lighting, heating, or alarm systems.

### Light as a Service (LaaS)

Under this model, lighting is provided and utilised as a service. It simplifies the planning of new installations, refurbishments, and the correct operation of a lighting system for the operator. In contrast to the project model, the customer does not buy a lighting system, but secures light for a fixed period of time based on a number of clearly defined performance criteria agreed with the provider. Payment is made in the form of regular service payments – based on the extent to which the service is utilised.

### Lighting System Design Process (LSDP)

This is a planning process for lighting systems. It is described in the technical specification DIN SPEC 67503. Fundamental design considerations for high-quality, energy-efficient lighting are integrated into the installation, commissioning and operation of a system that meets user requirements as comprehensively as possible. It also includes a risk analysis for safety lighting. The process supports the implementation of regulatory measures and the development of testing requirements.

### Look-down sensors

Internal look-down sensors mounted on the ceiling measure the light reflected directly beneath them in a room. They are installed at workstations.

### Look-out sensors

Internal look-out sensors detect the daylight coming in through the windows. They are installed at workstations.

### Mains switches

Mains switches are the simplest components for controlling light. Mains switches themselves should not be regarded as interfaces, as they transmit no information; they merely initiate or interrupt the power supply to the light source. However, a switch can be operated via interfaces.

### Matter and Thread

Matter and Thread are complementary standards. Matter is a standardised, manufacturer-independent platform that ensures software compatibility. Thread and Wi-Fi are networks which are used by devices to communicate. Matter uses the Internet Protocol (IP) for communication between products of different brands. Wi-Fi and the Thread protocol are IP-based and serve as the basis for Matter.

### Mesh networks

Zigbee and Thread are energy-efficient mesh networks. In a mesh network, multiple devices relay the signal. In this way, individual Thread devices with a permanent power supply strengthen the network.

### MQTT

Message Queuing Telemetry Transport (MQTT) is an alternative to BACnet. As a lightweight protocol, MQTT enables the efficient and flexible control of light management systems. It seamlessly integrates lighting systems with other building functions and works on the publish-subscribe principle, which ensures fast and reliable communication. Building managers can monitor and control lighting systems remotely using MQTT messages.

Overall, MQTT offers a powerful solution for the integration and control of light management systems in modern buildings.

### Network interfaces

Network interfaces can be used to control light management systems directly. In this setup, the control gear essentially receives its own network interface. Data is transmitted via a wireless or wired (LAN) network. Network interfaces are often used for LED systems.

### Parameterisation

Addresses are assigned to the control devices. The bidirectional communication of modern lighting systems enables individual parameterisation of the components:

- 1) Luminaires
- 2) Sensors
- 3) Control elements

### Push-buttons and smart light switches

Programmable push-buttons differ from power switches in terms of their function and technical design. They do not disconnect the power supply to the luminaire, but send pulses directly to luminaires (wirelessly, for example) or to higher-level control components. Depending on the type, these Wi-Fi switches and push-buttons can also be programmed to recall different lighting scenes directly.

### Semi-automatic mode

Semi-automatic operating mode for motion and presence detectors switches the

lighting on when a button is pressed. Detectors with a light control option initiate the regulation process. Once presence or movement is no longer detected, the run-on time begins, after which the lighting is switched off or the regulation is terminated.

### Swarm function

Anyone sitting alone at their desk in a multi-person office often works in an isolated 'island of light' – because the rest of the room remains unlit and, in low daylight conditions, may even be shrouded in darkness. Many people find this unpleasant. Furthermore, the stark contrasts between the workstation and the surroundings cause eye strain. A swarm function dims the lighting in unoccupied areas of the room to a pleasant basic level. Only when everyone has left the office is the light switched off in all zones.

### Zhaga

Zhaga is a voluntary partnership of international manufacturers from the lighting

industry. It develops uniform standards for mechanical, thermal and photometric interfaces of LEDs. This helps simplify the replacement of LED modules from different manufacturers (see page 48).

### Zigbee

Zigbee is a specification for wireless networks with low data volumes, such as home automation, sensor networks and lighting technology. The main focus of Zigbee is on short-range networks within buildings (10 to 100 metres). However, ranges of several kilometres are also possible outdoors. The Zigbee Light Link profile can be used to control the lighting via Zigbee. It describes standard functions such as switching on and off, dimming, and the control of colour components.

## Literature

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## Standards

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DIN EN 12193 Light and lighting – Sports lighting

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

DIN EN 12464-2 Light and lighting – Lighting of work places – Part 2: Outdoor work places

DIN 13201-1 Road lighting

DIN EN ISO 52120-1 Energy performance of buildings – Contribution of building automation, controls and building management

CEN/TS 17165/DIN SPEC 67503

Light and lighting – Lighting system design process

DIN CEN/TS 18036 Light and lighting – Commissioning of lighting systems in buildings

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

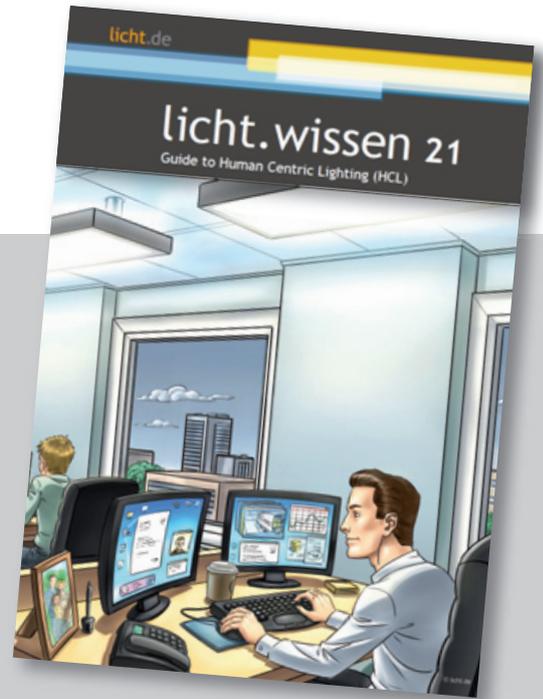
DIN/TS 67600 Complementary criteria for lighting design and lighting application with regard to non-visual effects of light

# licht.de publications

## licht.wissen 21

Guide to Human Centric Lighting (HCL)

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



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



**[licht.wissen 02]** In response to the significant renovation deficit in the education sector, the industry body licht.de published the technical manual 'Learning in a New Light' in 2023.



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



**[licht.wissen 19]** 56 pages on the biological effect of light on humans: booklet 19 reports on the latest research findings and uses real-life examples to explain the different approaches to dynamic lighting.

licht.wissen – PDFs can be downloaded free of charge from [www.all-about-light.org](http://www.all-about-light.org)

- 01 Lighting with Artificial Light (2016)
- 02 Learning in a New Light (2024)
- 03 Roads, Paths and Squares (2014)
- 04 Office Lighting: Motivating and Efficient (2012)
- 05 Industry and Trade (2018)
- 06 Shop Lighting – Attractive and Efficient (2011)
- 07 Light as a Factor in Health (2012)

- 08 Sport and Leisure (2010)
- 10 Emergency Lighting, Safety Lighting (2016)
- 11 Good Lighting for Hotels and Restaurants (2005)
- 12 Light Management (2025)
- 13 Outdoor Workplaces (2007)
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- 21 Guide to Human Centric Lighting (HCL) (2018)

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# All about light!

## Impartial information

licht.de provides information on the advantages of good lighting. The industry initiative provides extensive information material on all aspects of artificial light and its correct use. The information is impartial and is based on the relevant DIN and VDE technical guidelines.

## licht.wissen

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

## licht.forum

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

## www.licht.de

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



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Amelia-Mary-Earhart-Str. 12  
60549 Frankfurt am Main  
Tel. +49 (0)69 63 02-353  
Fax +49 (0)69 63 02-400  
licht.de@zvei.org  
www.licht.de