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Sport and Leisure

01

02

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[Cover] Artificial lighting permits sport and leisure activities at any time of day. It also makes sports and leisure amenities more attractive.

[01] The light sends out a signal that something really special is going on. Spectators also get a great deal of enjoyment out of sport.

[02] Good lighting for athletes, spectators and TV broadcasts needs to be carefully planned and professionally installed.

Editorial

By international standards, Germans have a great deal of leisure time. With six hours and 34 minutes a day to call their own, they are the second most leisured nation in the world. That is one of the findings of the Society at a Glance study published in 2009 by the Organisation for Economic Cooperation and Development (OECD). Many Germans use the leisure time at their disposal to engage in sports and recharge their batteries with wellness treatments. The umbrella organisation of German sport, the Deutsche Olympische Sportbund (DOSB), has more than 27 million members. Nearly twice that number of Germans are estimated to participate regularly in activities that are good for their health and fitness.

To profit from this enormous demand, sports and leisure facilities need to offer “products” that appeal. They also need to ensure a sense of wellbeing – including at night, when many recreational athletes wish to train or relax. This is where lighting comes in.

Sport is also a popular form of recreation for non-participants. This is evidenced by the rising spectator figures at sporting events and the high viewing ratings of sports broadcasts on television. These also require lighting.

Artificial lighting needs to be carefully planned, taking account of the nature of the sport, the speed of the movements executed, the size and velocity of balls, and the location of the observer. This booklet looks at general quality criteria and examines specific requirements. The information it contains is based on the European standard DIN EN 12193 “Sports lighting”.

It is important to appreciate one thing: good lighting is not expensive. Modern energy-efficient lighting installations can considerably lower the energy consumption and operating costs of public and private sports and leisure facilities. So they are investments that are quickly recouped – particularly where facilities are well patronised, where they raise the recreational profile of the town or area and where they act as a magnet for tourism.

03

Lighting quality features

The basic variables of lighting are illuminance, luminance distribution (brightness distribution), glare limitation (direct and reflected glare), direction of light and modelling, light colour and colour rendering properties of lamps. They are the quality features that define lighting quality.

DIN EN 12193 “Sports lighting” refers to the definitions of quality features in the basic standards DIN EN 12464 “Light and lighting – Lighting of work places” Part 1 (Indoor work places) and Part 2 (Outdoor work places).

Illuminance

Illuminance (symbol: E) plays a particularly significant role in determining how swiftly, reliably and easily a visual task is identified and performed. Measured in lux (lx), it indicates the amount of luminous flux from a light source falling on a given surface. Where an area of 1 square metre is uniformly illuminated by 1 lumen of luminous flux, illuminance is 1 lx.

Illuminance is measured at specific points on horizontal and vertical planes. To establish the illuminance for a playing area, for example, the surface is overlaid with a grid of assessment points. At each point, a measurement area is defined in a particular alignment at a specified height. The results of measurements at all assessment points enable the average illuminance to be calculated for the entire playing area.

Uniform brightness

The visual task is easier to perform if brightness is evenly distributed. Patches of bright light and dark shadow place a strain on the eyes by forcing them constantly to re-adapt.

Uniformity is measured on a plane and expressed as the ratio of minimum (Emin) to average (Eav) or minimum (Emin) to maximum (Emax) illuminance. Light is uniformly distributed where illuminance values at assessment points are similar.

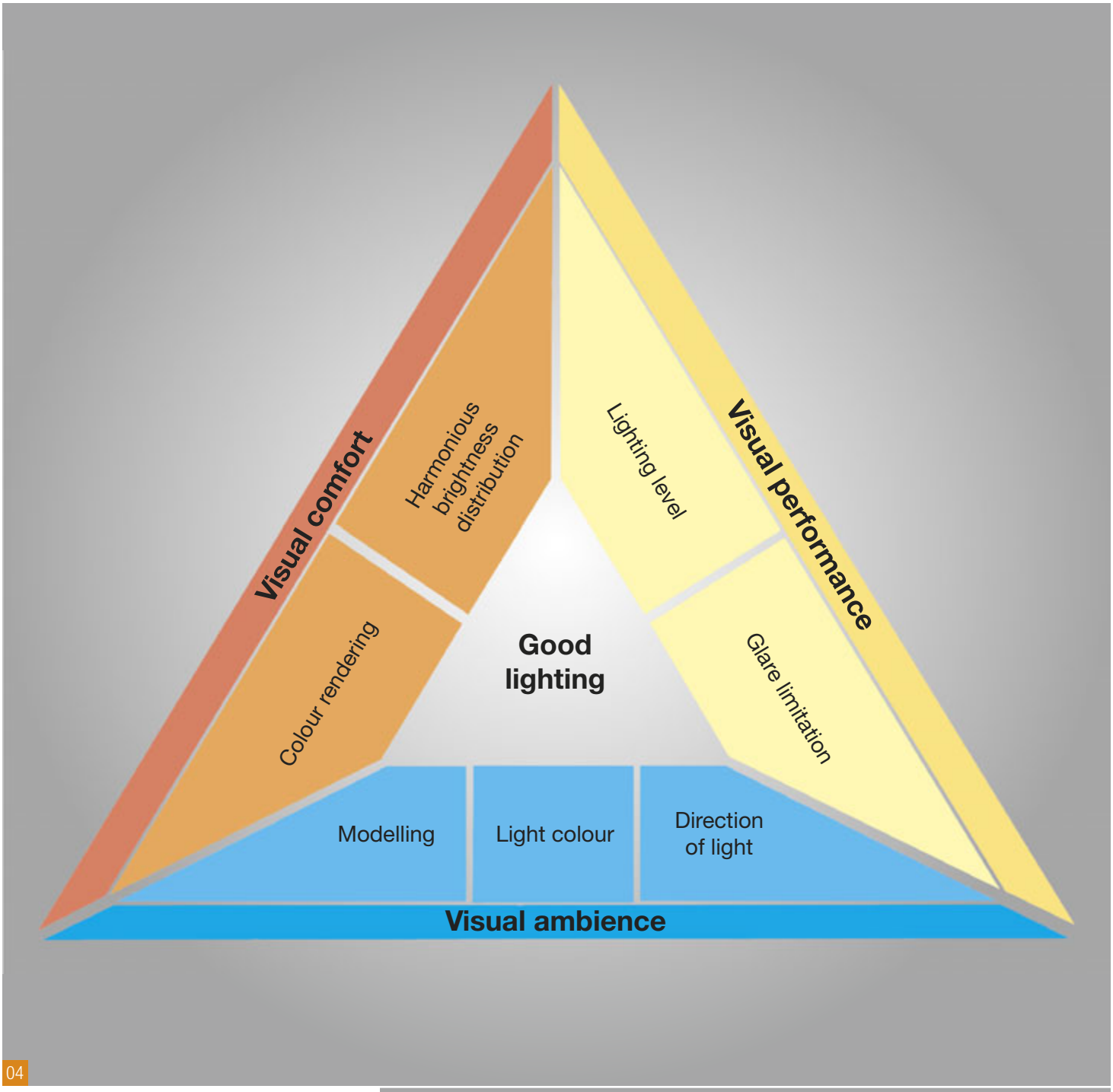
Maintained illuminance and maintenance factor

The average illuminance values set out in the standards are maintained values. Illuminance must never be allowed to fall below them. Once they are reached, maintenance is required. To ensure that this is not necessary immediately after the lighting installation goes into operation, a maintenance factor should be defined for the illuminance on installation when the lighting system is planned. It takes account of ageing and soiling of lamps, luminaires and – in enclosed spaces – room surfaces as well as lamp failure.

With regard to maintained illuminance values, DIN EN 12193 refers to two publications of the international lighting commission CIE: 97 “Maintenance of indoor electric lighting systems” for interiors and 154 “Maintenance of outdoor lighting systems” for outdoor installations.

Maintained illuminance is determined by four parameters:
> the lamp lumen maintenance factor (LLMF), which takes account of the decline in lumen output over the operating life of the lamp
> the lamp survival factor (LSF), which takes account of lamp failure during service life
> the luminaire maintenance factor (LMF), which takes account of the decline in lighting values as a result of soiling and ageing
> the room maintenance factor (RMF), which applies to indoor installations and takes account of the reflectance of room surfaces owing to soiling

[03] Luminaires need to be aligned so that they do not dazzle either athletes or spectators.



04

[04] Lighting quality features are interrelated. Visual performance, visual comfort and visual ambience are radically affected by certain quality features.

Lighting glossary

Lamp
No lamp, no light. The term “lamp” refers to an engineered artificial light source.

Luminaire
The term “luminaire” refers to the entire electric light fitting; it protects the lamp, distributes and directs its light and prevents it causing glare.

Luminous flux
Luminous flux Φ is the rate at which light is emitted by a lamp. It expresses the visible light radiating from a light source in all directions and is measured in lumens (lm).

Luminous intensity
Luminous intensity $\mathbf{I}$ is the amount of luminous flux radiating in a particular direction. The way it is distributed in the room determines the beam characteristics of luminaires, reflector lamps and LEDs. It is measured in candela (cd).

Visual task
Visual tasks are defined by light/dark and colour contrasts and by the size of details that need to be perceived. The harder the visual task, the higher the lighting level required.

Multiplication of the four individual maintenance factors produces the overall maintenance factor.

Maintenance factor and maintenance method need to be agreed between the lighting designer and the owner or operator of a facility right at the start of planning. Where a maintenance factor cannot be defined, the following reference maintenance factors are recommended: 0.67 for indoor and 0.7 for outdoor facilities.

Luminance distribution

Luminance (symbol: L) is the brightness of a luminous or illuminated surface as perceived by the human eye. It is measured in candelas per unit area (cd/m²). It impacts on visual performance and visual comfort.

Visual acuity, contrast sensitivity and thus the performance capacity of the eye improve with increasing luminance.

The luminance of a surface is determined by its reflectance and the illuminance on it. Hence the fact that a white room looks brighter than a room with dark furnishings when the illuminance is the same.

Visual comfort is negatively affected by
> excessively low luminance and excessive uniformity of luminance, which make for an unappealing, monotonous lighting atmosphere
> excessive differences in luminance, which cause eye fatigue as a result of the constant need for adaptation
> excessively high punctual luminance, which can cause glare.

Glare limitation

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

Shielding lamps helps guard against direct glare. Direct glare is rated by the UGR (Unified Glare Rating) method. This was developed for office lighting, so where lighting is provided by the high-bay reflector luminaires and floods that are commonly used in sports halls, its limiting values can only be observed up to a point. Protection against reflected glare is provided by matt surfaces. In addition – and especially where shiny surfaces are unavoidable, e.g. in a swimming pool – luminaires need to be appropriately arranged and angled.

In outdoor facilities, direct glare is established by the GR (Glare Rating) method described in publication 112 “Glare evaluation system for use within outdoor sports and area lighting” by the International lighting commission CIE. Here, the brightness of illuminated sports areas is correlated to the brightness of the light sources installed. The resulting ratios range from 10 for “no glare” to 90 for “unbearable glare” on a GR assessment scale. Standards set out maximum values for glare protection, normally GR = 50. GR values can only be established for sports with a playing area.

Direction of light and modelling

Shapes and surfaces should be clearly discernible (visual performance) and easily discernible (visual comfort). This calls for balanced, soft edged shadows. Shadow formation is influenced by direction of light, which is determined, in turn, by the distribution and arrangement of luminaires.

Highly directional light results in deep hard-edged shadows. Lack of shadow is also found disagreeable; it occurs where lighting is very diffuse.

Light colour

The light colour of a lamp indicates the intrinsic colour of the light that it radiates. This is determined by the colour temperature (correlated colour temperature T_{CP}) in Kelvin (K):

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

The light emitted by lamps of the same light colour can have different colour rendering characteristics.

Colour rendering

The colour rendering property of a lamp determines the way its light impacts on the appearance of coloured objects. The effect is rated using the colour rendering index R_a. This indicates how accurately the natural colour of an object is matched by its appearance under the relevant light source. R_a = 100 is the best rating; the lower the index, the poorer the colour rendering properties. For use indoors, lamps should not have a rating lower than R_a = 80.

Good lighting

Lighting quality is a product of visual performance, visual comfort and visual ambience (see Fig. 04):
> Visual performance:
The speed and accuracy with which visual tasks can be performed are crucially influenced by lighting level – resulting from illuminance – and the standard of glare limitation.
> Visual comfort:
Visual comfort is produced by a harmonious distribution of brightness and lamps with colour rendering properties that can at least be described as good.
> Visual ambience:
Lighting is a factor of room climate, which impacts on our mood and thus affects our personal sense of wellbeing. This visual ambience is fundamentally shaped by direction of light, modelling and the light colour of lamps.

05

06

Leonberg Sports Hall

	Before	After
Luminaires installed	luminaires with conventional ballasts	luminaires with electronic ballasts and energy management module
Number of luminaires	216	48
Lamps per luminaire	2 x 58 Watt fluorescent lamps, 26 mm diameter	6 x 80 Watt fluorescent lamps, 26 mm diameter
Total connected load	31,104 Watts	24,768 Watts
Energy consumption per year	130.667 kilowatt-hours	49,653 kilowatt-hours
Energy costs per year	20.907 euros	7,944 euros
Energy saved per year		81,014 kilowatt-hours = 62 percent
Cost saving per year		12,963 euros
CO_2 saving per year		48.6 metric tons CO_2

Energy-efficient lighting

Luminaires with optimised optical control elements, high luminous efficacy lamps, electronic operating gear, daylight utilisation and lighting management make for energy efficient lighting and a reduced carbon footprint. Lighting installations that are optimised in this way also offer the best lighting quality.

Lighting installations that are 15 years old or more need to be refurbished or completely renewed because they can no longer be operated efficiently. At the same time, many old installations can no longer guarantee the quality of lighting required. Investment in new equipment is quickly recouped as a result of the energy costs saved.

High-performance luminaires

Luminaires are efficient if they have high light output ratios and their intensity distribution curves are appropriate for the application. High-grade materials and professional standards of workmanship improve a luminaire's light output ratio; quality luminaires of this kind also have a long life.

Efficient lamps

Luminous efficacy is the yardstick of lamp efficiency. It indicates how much light (luminous flux in lumens) a lamp generates from the electrical energy (input in watts) it consumes. The higher the ratio of lumens to watts (lm/W), the more energy-efficient the lamp's operation.

The lamp industry has optimised the luminous efficacy of many light sources. In the case of the fluorescent lamp, for example, the luminous efficacy of standard lamps used to be low at an average of 65 lm/W; 26 mm diameter three-band lamps, however, achieve 93 lm/W (system luminous efficacy with electronic ballast) and 16 mm diameter models actually reach more than 100 lm/W. At the same time, the economic life of the lamps has increased – from 7,500 hours for a standard lamp operated by a conventional ballast to 24,000 hours in the case of a 16 mm diameter lamp with electronic ballast (EB).

Efficient ballasts

Optimising the operation of ballasts has also produced major savings. Electronic models are particularly efficient: even with the earliest EBs, system power consumption was below the lamp's power rating because they worked with a high-frequency alternating voltage. Now, EB development is advancing further, pushing forward even more the frontiers of ballast efficiency.

Daylight and lighting management

A great deal more energy can be saved by harnessing incident daylight from skylights or windows and combining it with artificial lighting. The artificial lighting is activated or slowly and gradually made brighter only when the available daylight is not sufficient.

Such systems are normally realised as lighting management solutions incorporating a daylight-dependent regulator designed to maintain a constant level of lighting with artificial and daylight components. The illuminance required at the work surface is thus kept more or less the same by raising or lowering the level of artificial lighting in response to changes in incident daylight. At certain times, daylight may also need to be shaded to prevent solar heat or glare.

Where motion detectors are integrated into the lighting management system, presence control is possible. Here, the lighting is instantly activated when a person enters the room and deactivated a few moments after the room is vacated.

Best practice: 62 percent saving

What can be achieved by refurbishment is evidenced by sports hall 2 at the Leonberg vocational school centre in the Böblingen area in Germany. The switch to new luminaires with new lamps and EBs as well as the incorporation of an energy management module cuts energy consumption, costs and carbon emissions by 62 percent (see "Leonberg Sports Hall" table, page 8).

Detailed information about "Lighting Quality with Electronics" has been put together by licht.de in booklet 12 of this series (see page 62).

[05] Fluorescent lamp light supplements the incident daylight and takes its place at night. Lighting management makes this interaction particularly energy-efficient.

[06] The Leonberg sports hall refurbishment reduced energy consumption by 62 percent.

EU prescribes efficiency

In April 2009, Commission Regulation No. 245/2009 came into effect in the EU. It prescribes a staged phase-out for discharge lamps (low-pressure and high-pressure) and ballasts with a poor energy balance. Certain lamps may no longer be placed in the EU market as of 2010 and the entire process will be completed by 2017. After that, only efficient lamps and ballasts will be available. The regulation is based on the Energy using Products (EuP) framework directive (2000/32/EC).

Saving energy with partial lighting

Where sports areas are regularly used not only for top-level sport (Lighting Class I) but also for ordinary training (Class III), lighting does not always need to be switched to the highest level. Partial lighting saves energy: all luminaires are activated for Lighting Class I, only a certain number of them for Class II and even fewer for Class III. However, the required quality of lighting needs to be ensured in all classes. Where partial lighting is planned, it needs to be taken into account early in the design phase.

Lighting for television

Lighting needs to meet higher requirements for television broadcasts than for athletes and spectators – both in qualitative and in quantitative terms. Television pictures can only be good if the lighting conditions are right for TV cameras.

Where live broadcasts and TV coverage are planned, sports facility lighting needs to take account of the special requirements they present. The lighting needed for the sport itself, with predominantly horizontal illuminance, is not enough for television pictures. For one thing, the positioning of luminaires needs to be different. So an existing lighting installation cannot simply be adapted to make it “TV-compatible”.

No special requirements need to be observed for videoing training. Standard-compliant general lighting in line with DIN EN 12193 is normally sufficient for that.

Direction of light is crucial

What is generally crucial for television pictures is the illuminance generated at grid points in the vertical plane: vertical light incidence alone is what makes it possible to show the expressions on athlete’s faces in action. For this, vertical illuminance needs to be calculated in the direction of the four boundary lines of the field or in the direction of the precise camera positions.

If the light is only to be directed onto the players from the direction of the cameras, a vertical assessment area facing the boundary line is defined above each point of the calculation grid – i.e. the playing area. The entire assessment plane in the direction of all four boundary lines (orthogonal directions) is 1 or 1.5 metres above the ground.

If vertical illuminances in the direction of precise camera positions are calculated and realised for lighting for television, special software is required. This aligns the assessment areas above each grid point with the surface normal in the direction of the camera.

The advantages of this planning method:
> The lighting installation supports better pictures because it is optimised for the broadcast cameras.
> The installation is more energy-efficient and economical because fewer luminaires and floods are required.
> It offers more freedom for positioning luminaires than planning “player lighting from the camera angle” because, in the latter case, floods can normally be positioned only at the sides of the playing field. This is the type of lighting in most widespread use today.

Lighting for good image quality

Lighting for television presents higher requirements in terms of colour rendering, illuminance and uniformity of illuminance. Lamps should have at least a good colour rendering rating (R_a index ≥ 80). The level of illuminance needed depends on the sport, the camera-to-subject distance and the standard of pictures required. In the case of high resolution television (HDTV), for example, 800 lx average illuminance in a camera direction is the minimum requirement for soccer. For better quality images and for zoom and super slow motion shots, the illuminance needs to be 2,000 lx.

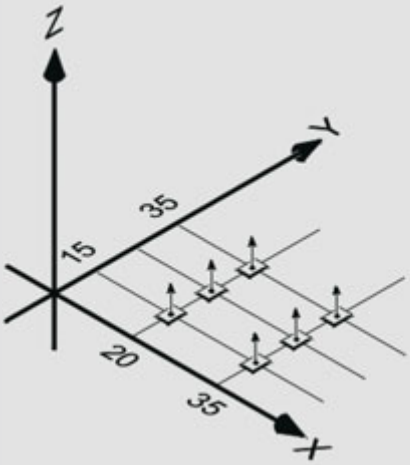
Lamp light colour is important particularly for broadcasts that commence in daylight but continue through dusk into the night. Daylight white lamps with a colour temperature of 5,200 to 6,000 Kelvin are suitable for mixing with daylight.

Lighting installations for television broadcasts should always be realised with the help of specialised lighting designers.

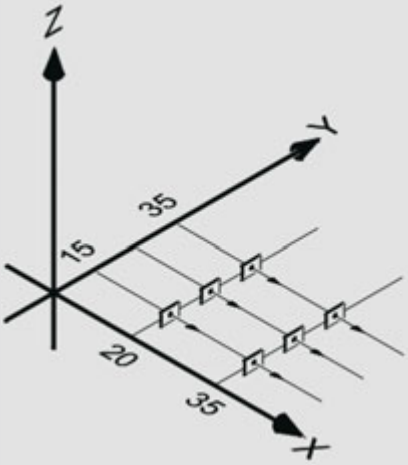
[07] Calculating horizontal and vertical illuminance as well as the illuminance in the direction of the camera

[08+09] The playing area as a calculation grid: good television pictures depend on tailored lighting.

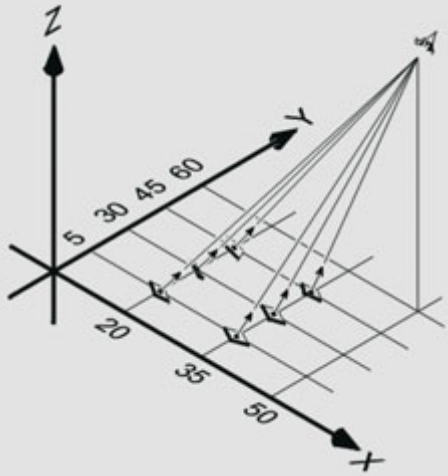
Illuminance



horizontal illuminance



vertical illuminance



illuminance in the direction of the camera

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Emergency lighting

For many sports and leisure facilities, mains-independent emergency lighting is mandatory. Its purpose is to permit athletes, spectators and staff to leave the building or outdoor facility safely in the event of a power failure.

Where lighting fails, the simultaneous presence of a large number of people means a risk of accident: the reason for the power failure is unknown, the surroundings are unfamiliar, fear spreads and very quickly results in panic. Escape sign luminaires mark the routes that lead outdoors, supplementary safety lighting for escape routes – ensuring at least 1x horizontal illuminance along the central axis of routes up to two metres wide – makes for better orientation and reduces the risk of accidents.

Safety lighting

The requirements that need to be met by emergency lighting are set out in the European standard DIN EN 1838. The fact that safety lighting is mandatory is enshrined in the Model Ordinance Governing Places of Assembly (MVStättV). Stipulations for safety lighting (protection of participants in sporting events) are also contained in the European standard DIN EN 12193.

The MVStättV covers
> assembly rooms which singly or jointly accommodate at least 200 persons
> places of assembly for at least 1,000 persons with open performance areas – areas less than 20 m² are not classed as performance areas
> sports stadiums accommodating more than 5,000 spectators with stands for visitors and with non-roofed sports areas

Because the dividing line between “sport” and “presentation” in performance areas is increasingly blurred, the requirements can also include outdoor sports facilities if
> they accommodate more than 1,000 visitors
> they have performance areas and
> the area for visitors consists entirely or partially of built structures. Visitor areas that are sectioned off by a barrier consist “entirely or partially of built structures” and are therefore also included.

Where an event can be brought to an orderly conclusion in the wake of a mains power failure, participant safety is ensured. Safety lighting needs to respond “instantly”. The level of safety lighting required depends on the sport in question; it is expressed as a percentage of the lighting level normally required for the sport:
> swimming – 5% for at least 30 seconds
> gymnastics, indoor facility – 5% for at least 30 seconds
> equestrian sports, indoor and outdoor facility – 5% for at least 120 seconds
> speed skating – 5% for at least 30 seconds
> bobsleigh and luge – 10% for at least 120 seconds
> ski-jumping, take-off and landing zone – 10% for at least 30 seconds
> downhill skiing – 10% for at least 30 seconds
> cycling (track racing) – 10% for at least 60 seconds.

For swimming pools with a depth of 1.35 m or more, the Pool Construction Guideline (1996) requires safety lighting to provide 15 lx illuminance at the water surface.

Detailed information about “Emergency Lighting, Safety Lighting” is provided by licht.de in the booklet licht.wissen 10 (see page 62).

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[10] If lighting fails, panic can ensue – especially where large numbers of people are assembled. Escape sign luminaires mark the routes that lead outdoors, supplementary safety lighting facilitates orientation

[11] Escape sign luminaires run on emergency power, so they are not affected by a mains power failure.

[12+13] Safety signs need to be clearly identifiable so that, in the event of a power failure, escape routes can be noted and followed even by people who are not familiar with the surroundings.

14

Lighting and environment

Sports and leisure facility lighting has the potential to cause “light pollution”: neighbours feel dazzled, insects are attracted by the light. This applies to outdoor facilities, especially to sports grounds and stadiums.

Avoiding light immissions

Carefully calculated mounting heights and well-shielded asymmetric floods prevent light trespass in the vicinity of sports grounds.

Some floodlighting installations designed for certain types of lighting are fundamentally incompatible with the goal of avoiding light immissions. In the case of stadiums equipped with lighting for television, the relevant limits are inevitably exceeded. And in certain ball sports such as baseball or golf, stray light needs to radiate upwards so that high-flying balls can be clearly made out.

Protection against “light pollution” is afforded by the Federal Ambient Pollution Control Act (BImSchG). However, no actual ceilings are defined in either statutes or administrative implementing regulations. So the measuring and assessment methods used – and the maximum admissible levels based on them – are those of the German lighting society (Deutsche Lichttechnische Gesellschaft – LiTG).

Immission control

The Immission Control Committee of Germany’s federal states (Länderausschuss für Immissionsschutz – LAI) has adopted these methods and ceilings in its guideline “Hinweise zur Messung und Beurteilung von Lichtimmissionen” (Measurement and assessment of light immissions) and recommends that they should be applied by environmental protection agencies. A number of federal states have also issued “lighting guidelines” in administrative regulations.

The LAI guideline is concerned with two criteria:
> Room illumination – For illuminated residential interiors, the assessment criteria used is illuminance in the window plane.
> Discomfort glare – The dazzling effect of a luminaire or lighting installation is established on the basis of the brightness contrast between the luminaire or luminous surface and its surroundings from the vantage of an affected local resident, the dimensions of the luminous surface and its distance from the resident.

The issue of light immissions is also addressed in Publication 150 “Guide on the limitation of the effects of obtrusive light from outdoor lighting installations” from the International Lighting Commission CIE, which contains references to DIN EN 12193. It also sets out limits for room illumination and neighbourhood glare. In Germany, however, the requirements that apply here are those of the LAI.

The CIE publication puts forward two more criteria and limiting values for them:
> glare from non-road lighting installations affecting road users
> sky glow.

Lighting and insects

Artificial lighting attracts insects, so there is a risk that it could interfere with the natural habits of nocturnal animals. What makes light attractive is its UV content. This could be sufficiently reduced by the use of high-pressure sodium vapour lamps but its yellowish light is strange to human eyes and does not meet standard requirements for competitions.

The design of the luminaires chosen can also reduce the appeal for insects: asymmetric floods without lateral light outlets are a good choice.

Sports grounds are most frequently illuminated during the dark months of winter, late autumn and early spring. So artificial lighting is mostly used at times when insects are not active anyway.

[14] Exemplary: The light cast by these floods is directed exclusively onto the sports ground; the very low level of stray light is below the permitted limits.

Table numbers

In DIN EN 12193, the tables are consecutively numbered and the sports they cover are assigned in a list. The table numbers shown in this booklet are identical to those assigned in the standard. In the booklet, the relevant sports are additionally identified in the table.

Lighting classes

DIN EN 12193 distinguishes between different lighting classes with different requirements (see also “Three lighting classes” on this page). In the case of a soccer field: 75 lx illuminance is sufficient for training sessions and local league matches (Class III), 200 lx is required for district and regional league matches (Class II) and a considerably brighter 500 lx is needed for state and major league games (Class I, not for television)

A.21 Soccer

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	200	0.6	50
III	75	0.5	55

Illuminance

The tables set out average (E_{av}) horizontal (E_h) or vertical (E_v) illuminance. Unless stated otherwise, the value stated in the standard refers to the principal playing area

Glare limitation

GR stands for glare rating and refers to the method used to calculate glare limitation (see page 7) in outdoor lighting. GR values can only be calculated for persons in the playing area.

Uniformity

The uniformity of the lighting is expressed as the ratio of minimum (E_{min}) to average (E_{av}) illuminance, in this case horizontal (E_h) illuminance.

Tables for each sport

DIN EN 12193 “Sports lighting” summarises the minimum lighting requirements for each sport in a table. This booklet also contains tables but looks only at key details and does not cover all the sports referred to in the standard.

Apart from the data presented in the tables in this booklet, the table for each sport in the standard cites other quality requirements. These relate to the colour rendering properties of lamps and to the reference areas to which all the stipulations in the table apply. Also defined are the grid points for the reference areas where calculations and measurements should be performed.

Competition level	Lighting classes		
	I	II	III
International/national	•		
Regional	•	•	
Local	•	•	•
Training		•	•
School/recreational sport			•

Reference areas

The reference areas identified for each sport are divided into
> a Principal Area (PA) and
> a Total Area (TA).
In most cases, the illuminance and uniformity of illuminance requirements apply to the Principal Area of the sport.

Three lighting classes

Lighting requirements for a youth team soccer match are not as high as those for a national team game. To meet these diverse requirements for both players and spectators, DIN EN 12193 sets out three lighting classes: the higher the competition level and the farther the spectators away from the action, the higher the lighting class needs to be. Lighting class III presents the lowest requirements.

Lighting class I: Top level competition events, top level training; spectators: long viewing distance
Lighting class II: Medium level competition events, power training; spectators: moderate viewing distance
Lighting class III: Low level competition events (usually no spectators), general training, general school and recreational sport.

15

16

Outdoor and indoor facilities

Because of different lighting requirements, sports and leisure facilities are divided into two locational categories: outdoor facilities (mostly sports grounds) and indoor facilities (mostly sports halls). Each can be “general”, if usable for different sports, or “special”, if designed for only one sport, such as tennis.

Sports grounds

Luminaires suitable for sports ground lighting include round or rectangular floods and spots with an asymmetrical or symmetrical beam. The luminaires are commonly mounted on four or six masts positioned at the sides of the playing field, which is usually rectangular.

Certain sports, such as tennis, are played only on courts designed exclusively for them. These sports often present special visual requirements and call for a luminaire arrangement that differs from the standard sports ground solution.

Floodlights should always be mounted as high as possible so that players are not dazzled when they look up at a high-flying ball. The arrangement and lighting characteristics of the luminaires determine the glare situation for both players and spectators. It is important to bear in mind at the design stage that spectators also need to be protected from glare. Some floods may need to be adjusted or shielded accordingly. However, glare cannot be ruled out altogether.

Shadows on the playing field must not be too harsh. Floodlight beams should therefore overlap. To avoid cast shadows, no point on the playing field should be lit only from one direction.

Sports halls

Most sports halls are suitable for many different sports. Some are also used for non-sporting events, e.g. events staged by local clubs and associations. The lighting needs to provide good visual conditions for all forms of use. So before any move is made to design a lighting installation for a sports hall, it has to be established which sports are going to take place in it and what other forms of use are anticipated (see “Multi-purpose halls”, page 5). One thing that must always be ensured is a level of lighting high enough to meet the requirements of the sport that presents the most demanding visual task.

Good general lighting alone cannot meet all requirements. Special-purpose sports halls, in particular – those designed specifically for sports such as tennis, squash, riding or shooting – require supplementary lighting.

Arrangement of luminaires

The arrangement of luminaires needed for general lighting depends on the lighting requirements set out in DIN EN 12193 and on the specific geometry of the hall. A regular luminaire arrangement is customary. Whether luminaires are recessed, surface-mounted or suspended depends on the height of the hall and the type of ceiling. Luminaires for 26 mm or 16 mm diameter fluorescent lamps, round or rectangular spots, high-bay reflector luminaires and floods for metal halide lamps are a suitable choice. Luminaires for sports halls need to be impact-resistant.

Good colour rendering

Lighting is not required only to make a sports hall bright; it should also ensure an agreeable atmosphere. This applies especially where a hall is used for sports with an aesthetic dimension, such as dancing, as well as other, non-sporting events. Lamps of warm white or neutral white light colour are thus recommended and colour rendering should be good to very good. (colour rendering index $R_a \geq 80$).

In partitionable sports halls, the direction of play and the main viewing direction swing through 90 degrees when the hall is divided. Here, luminaires need to be glare-suppressed for every viewing direction – something which is similarly recommended for non-partitionable halls.

[15] Floods and spots mounted on masts are an appropriate choice for sports ground (outdoor facility) lighting.

[16] In sports halls (indoor facilities), a regular arrangement of luminaires is customary. Options include luminaires for fluorescent lamps – as used here – as well as high-bay reflector luminaires and floods.

General outdoor sports facilities

General sports grounds are mainly used for ball sports: soccer, American football, baseball, hockey. The lighting requirements for these sports are broadly similar.

Soccer, American football

Most sports grounds – in Europe at least – are designed for soccer. So, to accommodate the world's most popular sport, 105 x 68 m have become standard dimensions. The size of field needed for baseball or fistball, hockey and American football varies but the lighting requirements for these sports are basically the same as those for soccer.

The distances a player needs to see on the pitch are normally less than 100 m. So for training and recreational sport (Lighting Class III), DIN EN 12193 stipulates a low horizontal illuminance of 75 lx. For competition matches with spectators, however, much brighter lighting is required because lines of sight for spectators can be considerably longer than for players. The same applies to American football.

Baseball, hockey

Baseball and hockey, which are played with relatively small balls, have higher visual requirements than football so they need higher illuminance. For baseball, the standard makes a distinction between infield and outfield areas.

Most of the action in baseball takes place in the infield, where catcher and batter are positioned and perform the actions crucial to the game. The visual conditions here need to be better than in the outfield, where little play takes place. Hence the higher illuminance required for the infield.

To enable players to judge the speed of the ball accurately, uniformity of lighting is particularly important. This should be no less than 0.7 (baseball: infield) for lighting classes I and II.

A.21 Soccer/American football

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	200	0.6	50
III	75	0.5	55

A.22 Hockey

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	200	0.7	50
III	200	0.7	55

A.14 Baseball

Class	Horizontal illuminance (infield) $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Horizontal illuminance (outfield) $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	750	0.7	500	0.5	50
II	500	0.7	300	0.5	50
III	300	0.5	200	0.3	55

[17] A sports field generally measures 105 x 68 metres – dimensions that are determined by soccer.

[18] Good lighting is important for players so that they can follow every move on the pitch. However, spectators also want to see all the action, so the lighting design has to take account of their needs too.

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A.13 Athletics

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	200	0.5	55
III	100	0.5	55

[19] The Berlin Olympic Stadium at the close of the 2009 World Championships in Athletics: a second lighting installation was built for the events in addition to the soccer lighting.

[20] Sports grounds that cater for athletics require more light than a soccer sports field. As a general rule, it is enough to fit the normal sports ground lighting with more floods and with more powerful lamps.

Athletics

Where sports fields are surrounded by running track for athletics, the sports ground lighting needs to be suitably dimensioned. As a general rule, a six-mast system will suffice but more floodlights and more powerful lamps are required.

Additional glare limitation measures should be considered for each athletic discipline. Care should be taken, for example, to ensure that no luminaires are positioned in the main line of sight at the pole-vault. Another special requirement is the need for 1,000 lx illuminance at the finish on running tracks to enable judges to reach reliable decisions and ensure that the photo-finish camera provides clear pictures.

Berlin Olympic Stadium

Athletics facilities in general sports grounds require special attention – a fact that becomes obvious at top level competitions. At the Berlin Olympic Stadium a new lighting system was installed for the 2006 Soccer World Cup. However, its light was not designed to cater for international competitions on the track around the pitch. So the lighting needed to be upgraded for the 2009 World Athletics Championships. The system installed was one that also made good television pictures possible.

The special thing about the new solution is that the lighting installation is intended for temporary use. After the 2009 athletics world championships, the luminaires and floods were dismantled and placed in storage until the next event at which the running track is required. And the next time it is used will not necessarily be an athletics competition: the system is designed so that luminaires and floods could be mounted and operated on its supporting structures for a pop concert or for other events.

Special outdoor sports facilities

A number of sports require facilities that are specially designed for them. These dedicated sports facilities present special visual requirements. The light provided by a standard lighting installation for a “general” sports ground is normally not right for the purpose; the luminaires need to be arranged differently.

Tennis

Tennis is a very fast game that places high demands on players’ visual acuity. There should be no sharp decline in horizontal illuminance for several metres beyond the boundary lines because these are areas where players are frequently active.

What is very important is that good contrast should be ensured between the ball (bright) and the background (dark). Players must not find the contrast too marked, however, so the background at the ends of the court (screen) should not be too dark.

Another important requirement is that the ball must always be uniformly illuminated as it flies over the court. This is essential to enable players to judge its speed and trajectory with accuracy. Wide-angle floodlights are therefore recommended. They should be mounted high enough to limit glare exposure for players.

Illuminated tennis courts have high recreational value. In summer, players can make use of cool evening hours; in spring and autumn, they can play long after the sun has set. Extra comfort and convenience is offered by lighting installations designed to permit a two-stage reduction in lighting level – from 500 lx illuminance (Lighting Class I) to 300 lx and 200 lx. Players thus have a choice of lighting levels to suit their requirements and budget.

Golf: Driving Range

Newcomers to golf start by practising their swing on a driving range. Artificial lighting extends the opportunities for practice after dark and helps players keep track of their ball when they are lined up at the tee with many others. To comply with DIN EN 12193, horizontal illuminance at the tee should be at least 100 lx, vertical illuminance at least 50 lx.

If lighting is provided only at the tee, it is impossible to monitor the trajectory of the ball. Keeping an eye on the ball, however, is something that every golfer needs to learn. To permit this, floodlights should be positioned so that adequate vertical illuminance – e.g. 10 lux – is ensured up to a distance of 150 m from the tee.

Nine or 18-hole golf courses – unlike driving ranges – are rarely furnished with full lighting facilities.

A.16 Tennis

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	300	0.7	50
III	200	0.6	55

A.26 Golf: Driving Range

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Vertical illuminance $E_{v,av}$ lx
I	–	–	–
II	–	–	–
III	100	0.8	50

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[21] Tennis places high demands on players' visual acuity. The ball should always be uniformly illuminated as it flies over the court.

[22] Practise, practise, practise: artificial lighting extends the time for driving range training beyond dusk. Floodlights (not shown here) ensure sufficient light up to 150 metres from the tee.

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Equestrian sports

Lighting for outdoor equestrian sports facilities is provided by floodlights and spotlights mounted on one or more high masts, depending on the size of the facility. The higher the luminaires are mounted, the lower the risk of glare. For racecourses, well shielded column luminaires at low mounting heights are also suitable; they are arranged parallel to the course.

In both cases, care must be taken to ensure adequate vertical illuminance on riders and horses so they can be clearly identified by judges, trainers and spectators. Good uniformity of lighting is also a prime requirement for equestrian sports. The speed of horse-racing makes high horizontal illuminance up to 750 lx necessary on the finishing straight. For other equestrian sports facilities (dressage, show-jumping), 500 lx is required for Lighting Class I.

[23] Inline skating track lighting needs to meet the same requirements as lighting for speed skating on ice.

[24] Riding arenas are illuminated with floods and spots mounted on one or more masts, depending on the size of the facility.

Boccia

On a dark evening, boccia players can only get their balls close to the boccino, or jack, if there is adequate light available. The illuminance required for the visual task ranges up to 200 lx (Lighting Class I) and uniformity of lighting is extremely important.

Mini-golf

The term mini-golf covers a variety of games, some more standardised than others. Distinguished by the size, shape and surfacing of their six to twelve metre long “greens”, they can be anything from a relaxing bit of fun to an intensely competitive sport. But whatever the level at which players compete, mini-golf is often played after dark.

Apart from skill and luck, players need good visual conditions to get round a mini-golf course in the fewest shots possible. Recommended lighting solutions are column luminaires set at low mounting heights and bollard luminaires. They need to be well shielded, i.e. designed to direct the light onto the putting surface without dazzling the players. Also, especially on large courses, path luminaires can be installed to provide additional lighting for the areas between holes.

DIN EN 12193 does not set out specific lighting requirements for mini-golf. These can be taken to be the same as for boccia, however, because the size of the ball and the nature of the visual task are similar.

Inline skating

Inline skating has almost entirely superseded roller-skating. Facilities include half-pipes and skating tracks. In Germany, most of the skating facilities for which lighting is provided are also used for competitions. Recommended solutions for their usually oval tracks are spots and luminaires on one or more masts, depending on the size of the facility. DIN EN 12193 makes no specific stipulations regarding lighting for such facilities. In the case of half-pipes, the lighting designer must also take care to ensure that the riding surface is free of shadows that could interfere with the visual task.

The lighting requirements are similar to those of outdoor facilities for speed skating on ice. Good lighting uniformity and minimum glare are particularly important features.

A.24 Horse Racing / Trotting / Gallop Racing

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Vertical illuminance Home stretch $E_{v,av}$ lx	$E_{v,min}/E_{v,av}$ Length	Cross	Vertical illuminance Back stretch and turn $E_{v,av}$ lx	$E_{v,min}/E_{v,av}$ Length	Cross	GR
I	200	0.6	750	0.6	0.4	500	0.6	0.4	50
II	100	0.4	300	0.6	0.4	200	0.6	0.4	50
III	50	0.2	100	0.3					55

A.13 Riding / Jumping / Dressage

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	200	0.5	55
III	100	0.5	55

A.20 Boccia*

*Also applicable to mini-golf

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	200	0.7	50
II	100	0.7	50
III	50	0.5	55

A.13 Inline-Skating*

*Requirements the same as for speed skating

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	200	0.5	55
III	100	0.5	55

Outdoor winter sports

Winter days are short. So it is useful for athletes to be able to train after dark. Winter sport is also a recreational activity: illuminated winter sports facilities are an added tourist attraction.

Cross-country skiing

Experience shows that the swathe of lighting for a cross-country ski trail should be four metres wide. To enable spectators to follow the action properly at competition events, illuminance levels at the finish need to be higher than those required by DIN EN 12193. Lighting for access routes is also important to enable coaches and spectators to reach the trail safely.

Downhill skiing

In the case of downhill skiing, athletes of all disciplines need light from the beginning to the end of the run. So the whole piste should be uniformly lit. The reference plane for horizontal illuminance is the surface of the snow. Lifts need to be separately lit at beginning and end; on the way up, stray light from piste lighting is enough to give users a sense of security. The above requirements also apply to snowboarding.

Ski jumping

Two moments are crucial for a successful ski jump: the moment of take-off at the bottom of the hill and the landing. So the lighting in those two areas is particularly important. To be able to judge touch-down points accurately and as early as possible, jumpers need good uniformity of lighting in the landing area. For the highest lighting class, a rating of 0.7 is required. Illuminance at the take-off should be at least 30 percent as high as in the landing area. Illuminance at ski jumps is measured on the surface of the snow.

[25] The take-off area of the Oberstorf ski jump is brightly illuminated. 30 percent of the illuminance in the landing area is required for standard compliance.

A.23 Alpine / Freestyle / Jumping

Class	Illuminance Alpine / freestyle $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Illuminance Jump run down $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Illuminance Jump landing $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	100	0.5	150	0.5	300	0.7	50
II	30	0.3	50	0.3	200	0.6	50
III	20	0.2	20	0.3	200	0.6	55

A.17 Cross-country skiing

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	20	0.3
II	10	0.3
III	3	0.1

A.28 Bobsleigh and luge

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	300	0.7
II	200	0.5
III	50	0.4

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Bobsleigh and luge

Negotiating the steep runs used for bobsleigh and luge calls for skill and lightning reactions. At high speed, the slightest of movements make the difference between victory and defeat. So it is extremely important for riders to be able to gauge every twist and turn of the run accurately.

Hence the need for relatively high horizontal illuminance levels and good uniformity. Dangerous dark zones that could interfere with the rider's visual task on the descent are thus avoided. The luminaires should be positioned along the run in such a way that they do not cause dazzling reflections on the surface of the ice.

On the ice

Speed skaters and ice hockey players prefer indoor facilities because the stability of the ice is not dependent on the weather and is easier to control. At higher altitudes, however, outdoor ice stadiums are certainly an alternative. In winter sports resorts, they are also an attraction for recreational ice skaters. Lighting is usually provided by systems based on four, six or more masts, depending on the size of the rink.

Curling is a sport in which players need to be able to gauge distances accurately. 200 lx horizontal illuminance on the playing area, 300 lx at the target (house) and good uniformity facilitate the visual task.

For facilities specifically designed for curling, the best lighting solution is a catenary-wire system. The wires should be strung across the relatively narrow playing area (masts at either side) and luminaires for high-pressure discharge lamps are the solution of choice.

[26] The speed skating track at the Inzell Ice Stadium is illuminated by column installations centrally positioned inside the circuit.

A.13 Speed skating

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	GR
I	500	0.7	50
II	200	0.5	55
III	100	0.5	55

A.19 Ice hockey

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	200	0.5

A.12 Curling

Class	Horizontal illuminance House $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Horizontal illuminance Rink $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	300	0.7	200	0.7
II	300	0.7	200	0.7
III	300	0.7	200	0.7

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Outdoor swimming pools

Because very few water sport disciplines in Germany are practised after dark, “ordinary” outdoor swimming pools are furnished with standard-compliant lighting only in exceptional cases. Leisure pools, thermal baths and private swimming pools, however, are illuminated.

Because of adverse weather conditions, swimming training – even where it is scheduled after dark – is often held indoors even during the summer. For recreational swimmers, on the other hand, evening or nighttime bathing in summer temperatures holds a special attraction. For their own safety, however, they should only visit illuminated swimming pools.

Underwater floodlights are imperative for pools at night. Without the light they provide, it is not possible to see the bottom.

[27] Light makes bathing after dark safer by providing a clear view of the water surface and the surroundings. It also creates a special atmosphere.

In the vicinity of outdoor pools, bollard luminaires or path luminaires on low columns ensure that the brightness of the underwater lighting continues over the edge of the pool and that visual contact is possible in every direction.

Access routes to an outdoor pool can be marked and illuminated by orientation luminaires. Care should be taken to ensure that no light from luminaires causes glare, either for swimmers or at the poolside.

A.27 Outdoor swimming pools

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Additional requirements for diving $E_{h,min}/E_{v,av}$
I	500	0.7	0.8
II	300	0.7	0.5
III	200	0.5	0.5

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General indoor sports facilities

For most ball sports, sufficient room for manoeuvre needs to be available for teams of several players. This applies to handball, basketball, volleyball and fistball as well as to the most popular team sport in the world – soccer. Combat sports and weightlifting require similar lighting.

[28+29] Room for manoeuvre for ball sports. The hall is uniformly illuminated in all lighting classes. Good lighting is also a must for corridors and secondary rooms.

Ball sports

Uniform illuminance throughout the hall is important for ensuring a clear view of the entire playing area. Volleyball and basketball have special requirements. To guard against glare for eyes following high-flying balls, luminaires for a volleyball court should not be mounted on the ceiling directly above the playing area. Nor should luminaires be positioned within a four-metre radius of basketball baskets.

Combat sports

In the case of combat sports, good visual conditions are crucial because athletes need to monitor each other's movements constantly and be on guard against sudden attack. Even the slightest movement can signal a strike; fast reactions are vital to avoid defeat. For this reason, the same horizontal illuminance values are required for sports like karate, judo and wrestling as for normal ball sports.

Weightlifting

Weightlifting is another sport that calls for strength and concentration. Lighting requirements are thus the same as for combat sports.

Small balls: hockey and table tennis

Hockey is a sport involving a small fast-moving ball. Even smaller is the ball used in table tennis. What is more, the balls change direction fast. So, for these sports, DIN EN 12193 requires 300 lx horizontal illuminance and good uniformity even for school and recreational sport (Lighting Class III). In the

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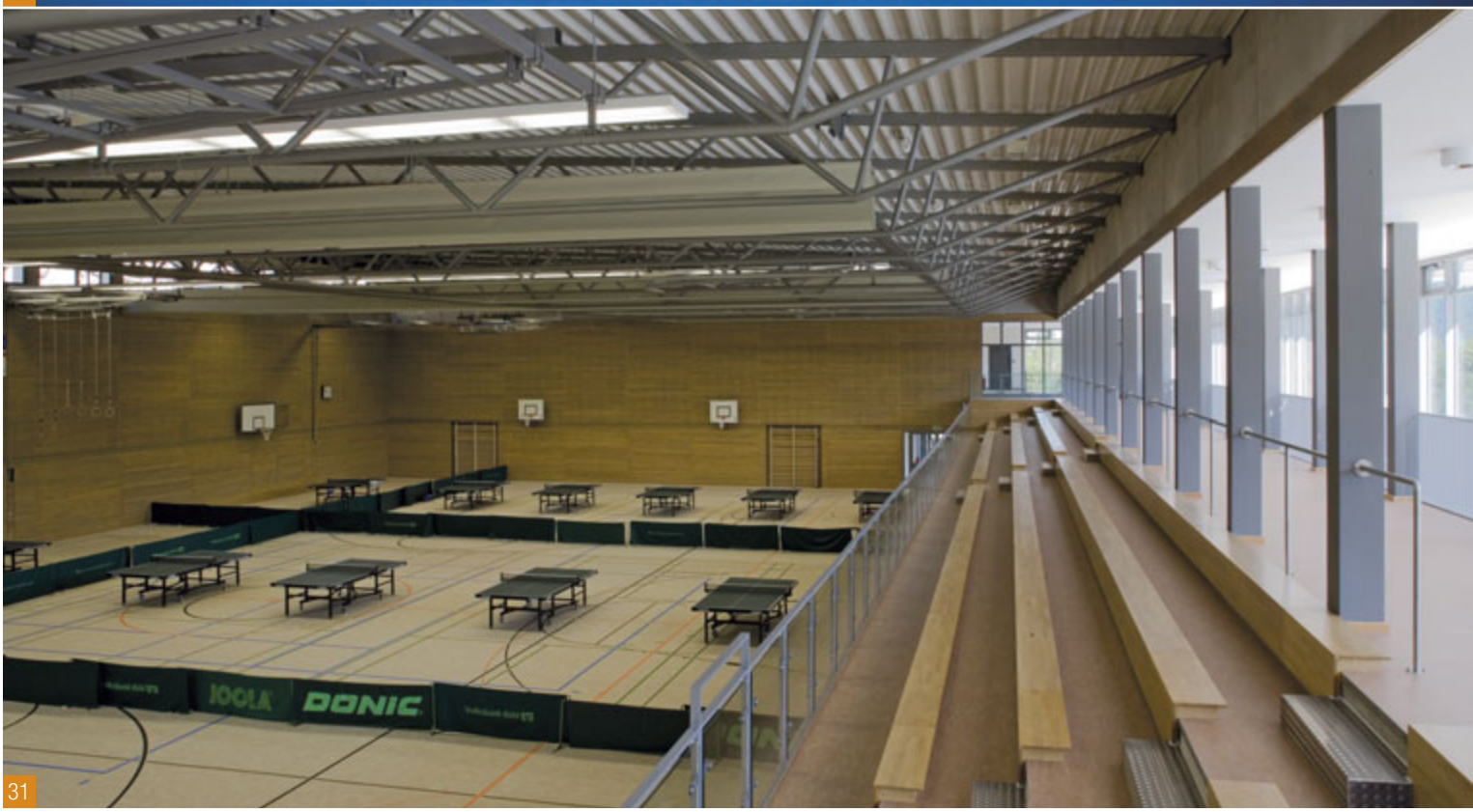

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other two lighting classes, the values required are the same as for sports that involve large balls.

For school and recreational sport as well as for training, normal hall lighting is enough. For competition table tennis, four supplementary floodlights are required per table. They should be positioned laterally so that they do not dazzle players and do not produce disturbing reflections on the table. What must always be remembered is that the area around the table needs to be illuminated for players to a depth of as much as five metres.

To enable the eyes to follow the trajectory of a high-flying ball, sufficiently high vertical illuminance needs to be provided at high levels.

Badminton

Badminton is played with a shuttlecock, which is also small and fast. To prevent players being dazzled when they look up at a high-arcing shuttle, luminaires should not be mounted directly over the court.
Like table tennis, badminton requires adequate vertical illuminance at high levels to prevent camouflage zones that would make it hard for the eyes to follow the trajectory of the shuttle. This ensures that the shuttle is easy to identify by a receiving player even at the highest point of its trajectory.

Fencing

Fencing is a sport characterised by lightning-fast movements. Because of the fineness of the foil blade and the fact that the principal visual task is focused on the opponent's torso, DIN EN 12193 requires higher vertical illuminance.

The 300 lx horizontal illuminance required for school and recreational sport is also higher than for most sports that take place in general sports halls; the requirements in the other two lighting classes are the same as for soccer.

Boxing

In boxing, the speed and force of movements in the ring necessitate horizontal illuminance of 500 to 2,000 lx. In addition, to ensure visual comfort for boxers, referee and spectators, DIN EN 12193 requires lamps with good to very good colour rendering properties. Good colour rendering is also a prerequisite for video and television recording.

The brightly lit ring in the middle of the hall is vital to the atmosphere of a boxing match. The lighting here is provided by narrow-angle luminaires mounted directly over the ring. During fights, the lighting in the auditorium is generally lowered to security level.

[30] The visual task in fencing is demanding and calls for relatively high illuminance.

[31] The small, fast-moving table tennis ball determines the visual task. The space used by players around the table also needs to be well illuminated.

A.2 Handball / Basketball Volleyball[1] / Fistball Soccer / Combat Sports / Weightlifting

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	200	0.5

A.1 Hockey / Table tennis / Badminton

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	300	0.7

A.1 Fencing

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Vertical illuminance $E_{v,av}$ lx	$E_{v,min}/E_{v,av}$
I	750	0.7	500	0.7
II	500	0.7	300	0.7
III	300	0.7	200	0.7

A.10 Boxing

Class	Horizontal illuminance Ring $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Vertical illuminance Ring $E_{v,av}$	Horizontal illuminance Training area $E_{h,av}$ lx
I	2,000	0.8	E_v should be at least 50% of E_h	300
II	1,000	0.8		300
III	500	0.5		300

[1] Luminaires should not be positioned directly over the court.

Special indoor sports facilities

Some sports can only be conducted on playing areas that are specially designed for them. To meet the relevant visual requirements, the arrangement of luminaires generally differs from the standard arrangement found in a general sports hall. In most cases, it also needs to be designed to suit a special roof construction.

Tennis

Being a very fast sport, tennis places high demands on players' visual acuity. So tennis hall lighting needs to cause little shadowing and minimal glare and should help maintain the marked contrast between ball and background. There should be no sharp decline in horizontal illuminance for several metres beyond the boundary lines because these are areas where players are frequently active.

To prevent tennis players being dazzled when looking at high-arcing balls, luminaires should not be positioned directly over the court. The ceiling must also be luminaire-free as far as three metres behind the base line because players very often look upwards there, especially when serving. An arrangement of luminaires parallel to the sides of the court is the customary solution.

Extra comfort and convenience is offered by tennis hall lighting that players themselves can adjust to suit their requirements and budget. To permit this, the lighting installation is designed for 750 lx illuminance (Lighting Class I requirement) and can be switched in stages down to 500 lx and 300 lx.

Luminaires used in tennis halls need to be impact-resistant.

Squash

The fast rubber ball used in squash presents high visual task requirements, especially in terms of lighting uniformity. It is much smaller than a tennis ball, frequently shoots upwards at angles close to the vertical and travels at speeds up to 200 kilometres an hour for most of the game. Because the vertical surfaces of the court permit complex ball trajectories, players have to change positions and viewing directions very fast, whilst always keeping track of their opponent's movements.

An effective solution here is a single row of luminaires parallel to the front wall and two rows of luminaires parallel to the side walls. The front wall luminaires should have an asymmetrical beam angled towards the wall and need to be well shielded on the players' side to avoid direct glare. Reflected glare is prevented by positioning the luminaires at least a metre from all walls.

Luminaires used in squash courts need to be impact-resistant.

Shooting

In shooting, participants basically look in one direction, towards the target. For good scores, high illuminance values are vital. For archery and shooting with crossbow, rifle or pistol, DIN EN 12193 stipulates 1,000 lx for targets 25 metres away and 2,000 lx for targets 50 metres away.

For the shooting range and its approach, 200 lx horizontal illuminance is adequate for all lighting classes. To permit optimum judgment of distance and firing line, good uniformity of lighting is important. Reflectors inclined at 30–40° towards the target are recommended for shooting ranges. They have the added effect of preventing direct eye contact with luminaires. For the firing point, indirect lighting is recommended to avoid reflections on the weapon.

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A.4 Tennis

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	300	0.5

A.1 Squash

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	300	0.7

[32+33] Good tennis hall lighting produces little shadowing and minimal glare and helps maintain a marked contrast between the ball and the background. An arrangement of luminaires parallel to the sides of the court is the customary solution

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Nine-pin and ten-pin bowling

Like shooters and archers, nine-pin and ten-pin bowlers have their eyes trained mostly on the target – the pins. However, the vertical illuminance needed here is not as high as for shooting and archery: 500 lx is enough for the area of the pins. This value applies to all lighting classes. For the bowling lane and approach, 200 lx horizontal illuminance is adequate – again for all lighting classes.

Although players always play to win, nine-pin and ten-pin bowling are not so much competitive sports as popular recreational activities. Standard-compliant lane lighting facilitates the visual task – but bowlers want more: they expect lighting that creates an agreeable atmosphere.

So special attention should be paid to lighting outside the actual bowling area. Accentuating, even indirect lighting – not too bright, not too low – is the key to an attractive lighting concept here.

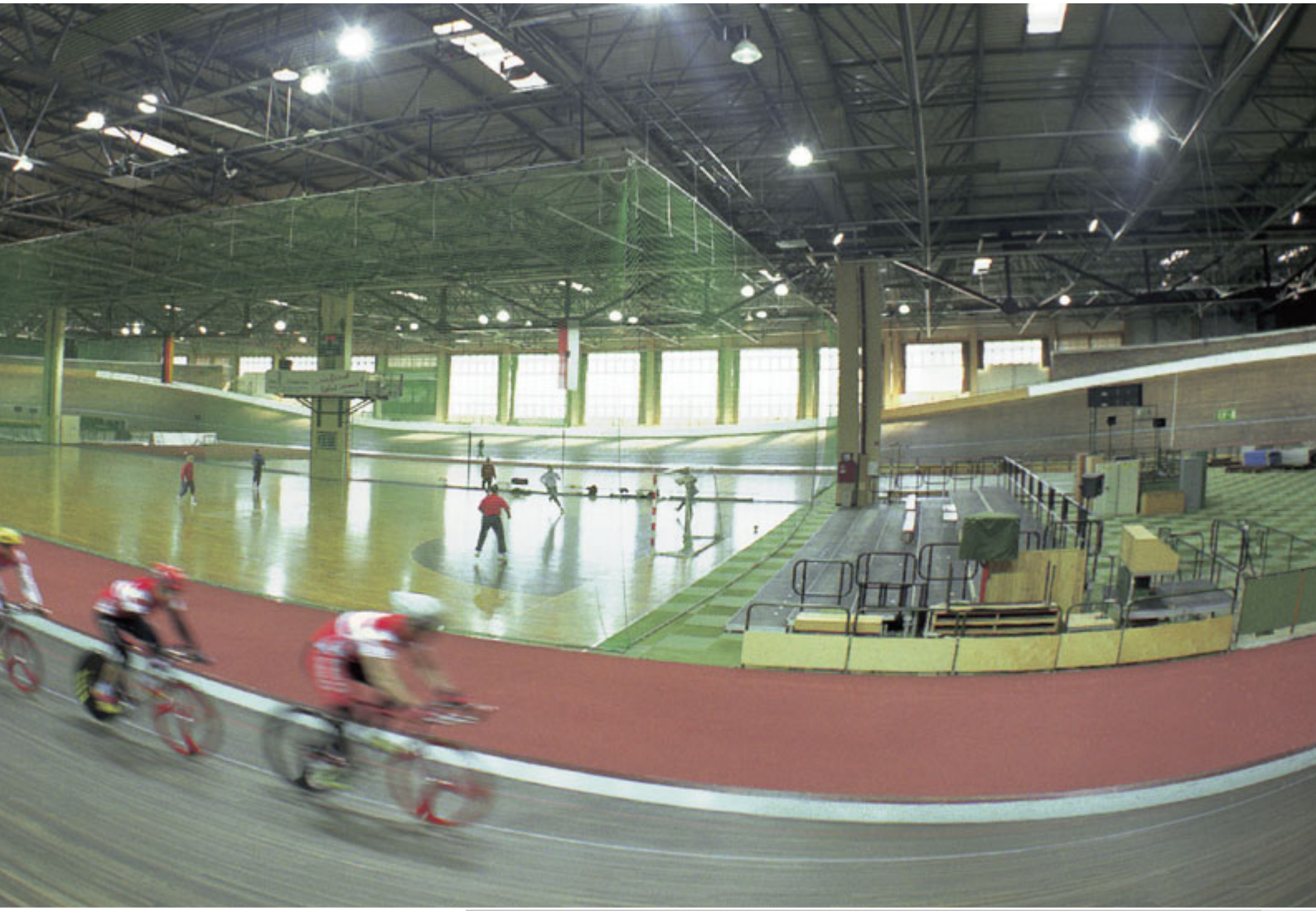
Equestrian sports

In halls for equestrian sports (jumping, dressage), lighting needs to be tailored not only to the visual requirements of human beings but also to those of horses. A horse's twilight vision is very highly developed, so it is more sensitive to differences in light than a human being. To avoid confusing and upsetting the animals, marked luminance fluctuations need to be avoided.

To ensure that all obstacles are readily identified, higher vertical illuminance is needed. Spectators, too, rely on this vertical illuminance to make out horses and riders clearly. Owing to the presence of dust and heightened humidity, all luminaires used in indoor riding arenas should be designed to a higher degree of protection.

Cycling

When track riders get going, they cannot stop fast – especially since their bikes are not fitted with brakes. Even so, they try to



stay as close as possible to the rider in front to get maximum benefit from his slipstream. To avoid collisions and painful falls, riders need to be able to gauge precisely what their opponents are likely to do, even at high speed. That calls for good visual conditions.

The illuminance values required by DIN EN 12193 apply to the surface of the track. The 1,000 lx vertical illuminance required additionally at the finish facilitates the visual task of the judges and plays a significant role in determining the quality of photo finish pictures.

A.5 Archery / Shooting / Bowling

Class	Horizontal illuminance Range		Vertical illuminance Target		Pins	
	$E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	$E_{v,av\ 25\ m}$ lx	$E_{v,av\ 50\ m}$ lx	$E_{v,av}$ lx	$E_{v,min}/E_{v,av}$
I	200	0.5	1,000	2,000	500	0.8
II	200	0.5	1,000	2,000	500	0.8
III	200	0.5	1,000	2,000	500	0.8

A.3 Equestrian

Class	Horizontal illuminance	
	$E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	500	0.7
II	300	0.6
III	200	0.5

A.2 Cycling

Class	Horizontal illuminance	
	$E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	200	0.5

[34] In sharp focus: 500 lx makes the pin area the most brightly lit point in the room.

[35] Cycle track lighting needs to make it possible for riders to gauge precisely what their rivals are going to do. That is vital for ensuring that collisions and painful falls are the exception, not the rule.

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A.3 Climbing halls

Class	Horizontal illuminance		Vertical illuminance	
	$E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	$E_{v,av}$ lx	$E_{v,min}/E_{v,av}$
I	500	0.7	500	0.7
II	300	0.6	300	0.6
III	200	0.5	200	0.5

A.2 Indoor playground* / Go-karting*

Class	Horizontal illuminance**	
	$E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	200	0.5

* Requirements the same as for general sports hall
** Lighting Class III for indoor playgrounds

Climbing halls

Indoor climbing is now an established activity, offering recreational fun and training opportunities “at the rock face” whatever the weather. The degrees of difficulty range from “beginner” to “advanced”. For a visual experience that is as natural as possible, a light colour similar to daylight is recommended. Lamps should also have good colour rendering characteristics (R_a index ≥ 80).

Climbers are all dressed in the kind of clothing worn by professionals and are equipped with fall arrest harnesses. However, being able to see properly is an equally basic safety requirement. For a start, this means the need for evenly distributed light: every wall should be uniformly illuminated with no marked differences in luminance.

Direction of light and modelling are also particularly important. The correct ratio of diffuse to directional light emphasizes the structure of the wall and makes holds and grips clearly recognisable. Incident light from the side and light from above prevent climbers themselves casting deep, disturbing shadows. Care must also be taken to ensure that climbers looking upwards or at holds at their side are not dazzled.

Indoor playgrounds

Children need exercise, want fun and welcome any form of variety. Indoor playgrounds fit the bill perfectly here, whatever the weather. A recreational facility for the whole family, they offer far more than an activity package for children’s birthdays. Rising visitor figures show that the concepts are right.

From a lighting viewpoint, the empty hall is comparable to a general sports hall covered by Table A.2. For recreational use (Lighting Class III), it thus requires 200 lx horizontal illuminance. So the arrangement of luminaires for an indoor playground can resemble that of a general sports hall. Because playground equipment blocks light, the illuminance at certain points may be too low but it should still be enough on the whole for children at play. To prevent overly dark conditions, light-coloured hall walls are recommended. They act as reflective surfaces for the light from the ceiling. Playground facilities that block out the light altogether should be confined to the occasional tunnel.

Go-karting

Go-kart tracks are as popular with recreational racing drivers as they are with dedicated motor sports fans. Indoor tracks not only offer a karting experience regardless of the weather; they also hold a special appeal as a venue for “private” events. Go-karts are fast but the speeds they reach are not exceptionally high for their size. Lighting requirements are therefore no higher than in a general sports hall; the stipulations for ball sports and cycle tracks (Table A.2) apply.

Note on outdoor facilities: The requirements for outdoor go-kart tracks in DIN EN 12193 are set out in Table A.18.

[36] Uniform light is right for the climbing wall. It should comprise a mix of diffuse and directional light tailored to suit the wall so that holds and grips are clearly recognisable.

[37] Fun and variety: Indoor playgrounds are treated for lighting purposes like general sports halls.

Indoor winter sports

Indoor winter sports are predominantly sports or recreational activities on ice. Because an ice surface is easier to control indoors, many athletes prefer indoor facilities to outdoor ones. In the few halls that exist for indoor skiing, the lighting requirements to be met are analogous to those for outdoor skiing. (see page 26).

Ice skating

Ice skaters like indoor rinks because they allow them to train whatever the weather. In most cases, rinks are used for all the different skating sports – ice hockey, speed skating and figure skating. So the lighting needs to be designed to cater for the ones with the highest visual requirements: ice hockey and speed skating. Any lighting meeting the needs of these two sports is also right for recreational ice skating, for which most indoor rinks are used on a regular basis.

Ceiling luminaires should be arranged in a uniform pattern above the playing area. As a general rule, care should be taken when selecting and arranging luminaires to produce as few reflections as possible on the shiny ice surface. Luminaires in indoor ice rinks need to be impact-resistant.

Ice hockey: Light for the puck

For ice hockey, lighting at the goal areas needs to be somewhat brighter than elsewhere on the pitch. The higher illuminance can be achieved in one of two ways – either by closer luminaire spacing above the goal or by fitting the goal lights with more powerful lamps.

Because of the speed and size of the puck, it is not always easy for ice hockey spectators to follow its movements. The perceptibility of a flying puck can be significantly improved by raising the luminance of the background, thus making the black puck stand out in sharper contrast. So the areas around the rink – including the spectator stands – should always be bright.

Curling

What counts in curling is ability to gauge distances. For that, players need a good eye and good visual conditions on the ice. DIN EN 12193 requires 200 lx horizontal illuminance for all lighting classes. In the “house” or target area, it should be 100 lx higher. To enable players to follow the path of a stone precisely, good uniformity of lighting is important.

A.3 Speed skating*

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	500	0.7
II	300	0.6
III	200	0.5

A.1 Ice hockey / Figure skating

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	750	0.7
II	500	0.7
III	300	0.7

* Note: Glare cannot be quantified. It can however be controlled by careful positioning of luminaires. The vertical illuminance at the finishing line should be 1,000 lx for photo-finish equipment and officials.

A.12 Curling

Class	Horizontal illuminance House $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Horizontal illuminance Rink $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$
I	300	0.7	200	0.7
II	300	0.7	200	0.7
III	300	0.7	200	0.7

[38] Calm before the storm: The fast game with the small puck calls for bright light with good uniformity.

[39] In recent years, a number of halls have recently been built for indoor downhill skiing. No special rules have yet been formulated for the lighting required in these new facilities. The requirements for outdoor downhill skiing apply analogously (see page 26).

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Multi-purpose halls

Using a hall not only for sport but also for other events can make good economic sense. But it needs to be planned as a multi-functional facility; retrofitting for changes in use is not possible. Multi-purpose hall lighting needs to be more technically sophisticated than ordinary sports hall lighting.

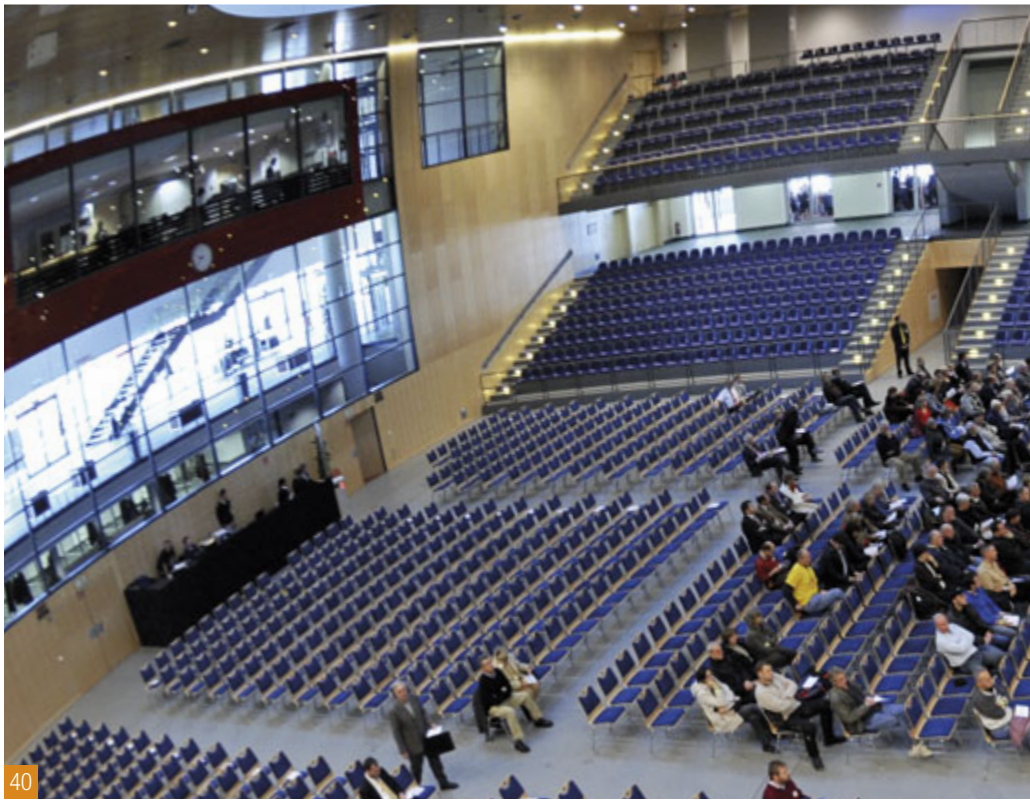
Basically any sports hall can be designed as a multi-purpose facility. Even an area of ice for ice hockey can be incorporated; it can be covered for other sports or for non-sporting events. One or two stages, comfortable stands, lowerable front-row seating in stands to permit more standing space – there are many possible and practicable options. Such a facility can also be used as a lecture hall or exhibition room, a venue for club events or stage performances or a hall for gala occasions.

All anticipated uses need to be known before the lighting design is realised so that the lighting can be designed to perform every function that is needed and that every lighting scene required can be realised. For an event such as a pop concert, temporarily installed supplementary luminaires are an option but generally remain the exception for reasons of cost. However, it is sensible to ensure that the required electrics are in place.

Dimmable lighting

Wherever possible, the general lighting should be dimmable. It should be flanked by supplementary lighting on separate circuits and fitted with a lighting control system that caters for all anticipated needs. In larger halls with multi-stage sports lighting for television broadcasts, lighting control is also generally useful for non-sporting events.

It is important to remember that such premises are always still sports halls, so all luminaires need to be impact-resistant. Lumi-



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naires that do not meet this requirement – e.g. spots installed for stage lighting at a height of less that five metres – need to be dismantled for sports activities.

Shielding for spots

Where high-pressure discharge lamps are used for sport, it must be remembered that they need ten minutes to cool down before they can be switched on again. The use of instant hot re-ignition gear is not recommended here – it is intended for emergencies (safety lighting) – because it shortens the life of the lamps. An alternative is to mount shields on spots. They should be designed to open and close at a selectable speed.


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[40+41] Multi-purpose halls are designed for sport and other uses. The lighting installed in them needs to cater for every anticipated occasion, from sports events to lectures and exhibitions.

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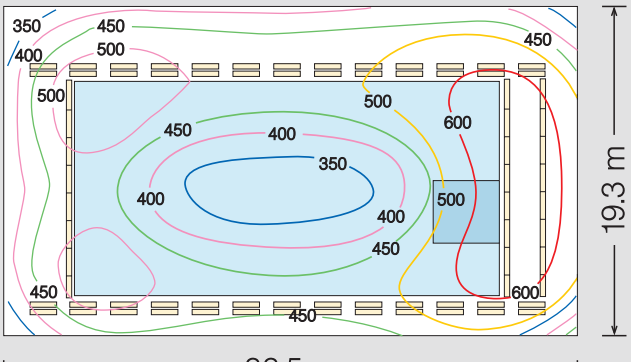

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A.6 Water polo / Competitive swimming / Synchronised swimming / High and springboard diving

Class	Horizontal illuminance $E_{h,av}$ lx	$E_{h,min}/E_{h,av}$	Additional requirements for diving $E_{h,av}/E_{v,av}$
I	500	0.7	0.8
II	300	0.7	0.5
III	200	0.5	0.5

Indoor swimming pools

Different disciplines present different lighting requirements for athletes in the water. Experience shows that good visual conditions for outsiders generally mean good visibility for athletes, whatever the discipline. However, lighting requirements can differ widely from one indoor pool to another.

Water sports

For water polo players, ambient brightness is a crucial parameter. Competitive swimmers, on the other hand, do not require as much light because their attention is focused on their lane. Swimming instructors, coaches and pool attendants need a good view of the water from the pool side. At competitions, spectators need to be able to follow the action in the pool from a considerable distance.

Reducing reflections

Because water reflects direct incident light so intensely, ceiling luminaires should be mounted at the perimeter of pools. Where this is not possible, reflections can be reduced by mounting luminaires with an asymmetrical beam over the water. For small pools, luminaires installed above the edge of the pool suffice.

Underwater lighting also reduces reflected glare from a pool surface, as well as making for a clearer view of the pool bottom. For synchronised swimming, underwater floodlights – designed for pool use – are imperative. For recreational bathers, the light they cast becomes a decorative pool feature. For water polo matches and for competitive swimming, however, underwater floodlights should be switched off.

Lamps with a colour rendering index of $R_a \geq 80$ – i.e. rendering to a standard higher than that required by DIN EN 12193 – enhance visual comfort and help create an atmosphere which recreational bathers find congenial.

High and springboard diving

Diving installations require supplementary lighting. This enhances the vertical illuminance throughout the diving area. Additional vertical illuminance is also required for judges – especially at the point of entry – because they need to assess the diver's performance from the side or from an oblique angle at the edge of the pool.

For springboard diving, the ratio of horizontal to vertical illuminance needs to be planned with particular care.

High degree of ingress protection and protection against corrosion

Because of humid, chlorinated or even salty air, luminaires for indoor swimming pools need to meet high standards of electrical reliability and protection against corrosion. Operational reliability calls for luminaires designed to high degrees of protection, at least IP 44 for lamp and ballast compartments. Quality luminaires designed for such applications feature additional corrosion protection and ensure years of service even in adverse conditions.

Important note: Luminaire fastening elements must also be corrosion-resistant; the most reliable fastenings are made of austenitic stainless steel

[42+43] Reflections on the water can be avoided by mounting ceiling luminaires at the pool perimeter. Luminaires positioned directly over the water should be designed for asymmetrical light distribution.

[44] Example of horizontal illuminance distribution in an indoor swimming pool.

Indoor leisure pools

Recreational swimmers go to pools for fun and not for muscle or cardio training. With fun pools and slides, islands and activity areas as well as extensive wellness zones with saunas and solaria, most leisure pool complexes offer a full range of facilities for entertainment, health and beauty.

Leisure pool lighting needs to meet the same basic requirements as lighting for "ordinary" indoor pools (see page 44), especially in terms of luminaire protection and corrosion proofing. However, greater emphasis is placed here on ambience and a stimulating lighting atmosphere. Supplementary lighting is also needed for the poolside activity areas, which can range from rustic scenarios to tropical paradises.

Setting the scene with light

The higher design requirements of a leisure pool are met by arrangements of elegant luminaires and a considered choice of light sources and light colour. In the water, underwater floodlighting adds a magical note to a stimulating world of cascades and fountains, grottoes and greenery, niches and stones. The dramatic lighting provided by concealed and visible luminaires can be supplemented by wallwashing or illumination of parts of the ceiling.

Ambience for "ordinary" indoor swimming pools

Paying more attention to ambience can also make "ordinary" indoor swimming pools more attractive for recreational swimmers: technically optimised high-design luminaires for general lighting, punctual warm-white lamps for accent lighting and underwater floodlights enhance the leisure experience.

[45] The butts beside the whirlpool set accents with dynamic colour-changing light. The coloured light is produced by LEDs.

[46] Leisure pool lighting sets the stage mainly for water. Lighting around the pool should be more atmospheric than in an "ordinary" swimming facility.


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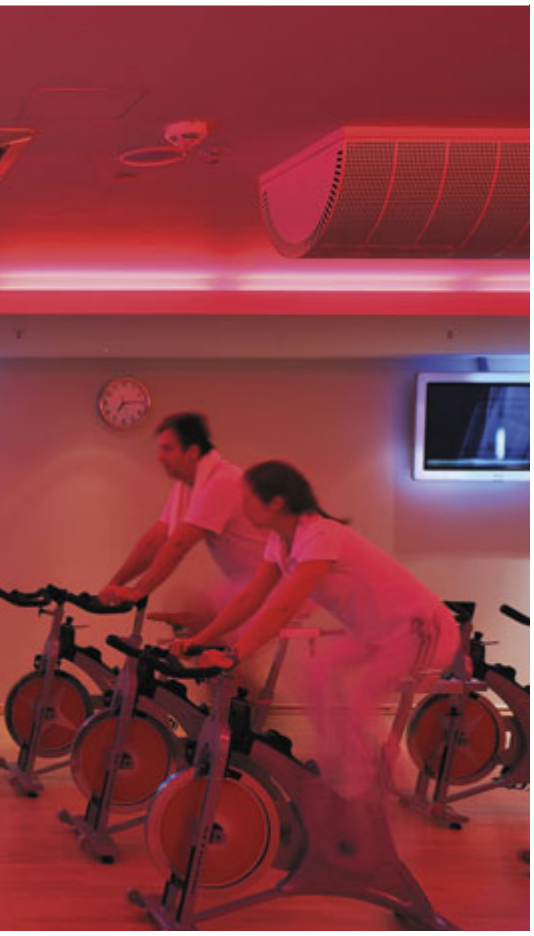
Fitness studios

Fitness studios – either as independent operations or as part of a sports facility complex – offer a host of opportunities for training. Options range from bodybuilding through personal workout programmes to gymnastics and other forms of group exercise. Workout areas with apparatus and exercise rooms are provided for the purpose.



Workout areas

The first requirement for lighting here is that it should make it possible for all apparatus to be operated safely. This calls for at least 300 lx horizontal illuminance in workout areas. The arrangement of luminaires should be defined by the arrangement of apparatus. It is important to ensure that information on screens and displays is not obscured by excessive reflected glare.

Apparatus and areas for exercises that are performed face-up are best grouped together. This is because these activities require different lighting to protect users from the glare that is unavoidable where luminaire faces are in direct lines of sight. Asymmetric luminaires mounted outside the direct glare zone on the ceiling offer considerable anti-glare protection.

Special lighting comfort is achieved where ceiling luminaires can be dimmed for zonal lighting control. Lighting can thus be better tuned to the needs of those training. Being differentiated, it also makes a more attractive impression as a whole. Supplementary accent lighting with wall luminaires, for instance, makes for a more informal atmosphere.

Exercise rooms

The lighting concept for workout areas can also be adopted for spinning, power step, stretching, bums-tums-and-legs and back-muscle training rooms. In at least one of the rooms, the light colour of the lamps should be warm white and the lighting dimmable. The lowered lighting helps make for a relaxing atmosphere for training units involving mental exercises.

Changing rooms

For changing rooms, standards designed for the working world require a uniform lighting level of at least 160 lx. For greater comfort and convenience, however, 300 lx is recommended. For one thing, the brighter light makes items in lockers or sports bags easier to find.

The higher lighting level also gives users a greater sense of security and signals cleanliness. Accent lighting makes for a less clinical lighting atmosphere, enhancing visual comfort and improving the visual appeal of the room.

For economical general lighting in communal changing rooms, 26 mm or 16 mm diameter fluorescent lamps are a particularly suitable option. For individual changing cubicles, more light sources are needed to provide adequate lighting. Here, downlights or other ceiling luminaires for compact fluorescent lamps – always one over each cubicle – are the right choice. Wall luminaires with halogen or compact fluorescent lamps are suitable providers of accentuating light.

[47] The arrangement of luminaires in the workout area should be determined by the apparatus. Horizontal illuminance should be no less than 300 lx.

[48] Bright and cheerful changing room lighting signals cleanliness and makes for a greater sense of security. 300 lx is better than the 160 lx minimum illuminance required for standard compliance.

[49] Taking the monotony out of spinning: the light changes colour in dynamic sequences based on the RGB model (red, green, blue) It is generated by RGB fluorescent lamps.

Service areas

The heart of every sport and leisure facility is formed by a sport or activity area. But that is not the only place where athletes and spectators need good lighting: the right light is also important in adjoining service areas, including corridors and passageways. Good lighting quality in these areas enhances the image of the facility as a whole.

Sauna

We take a sauna to recharge our batteries. So the surroundings should be restful. For the lighting designer, this means: elegant luminaires and accentuating light, bright for safe passage between sauna, plunge pool and shower, dimmed for rest rooms.

Both in the sauna itself and in the immediate surroundings, hygiene requirements are high. Extra luminaires should therefore be installed in all zones to raise the lighting level to at least 300 lx for cleaning.

Inside the sauna, special luminaires are required. In the immediate surroundings, the high humidity of the air calls for luminaires with a higher degree of protection – at least IP 44. Downlights for compact fluorescent lamps are a good solution.

Solarium

General lighting for a solarium also needs to be designed with care. The lamps that are used require a colour rendering index of $R_a \geq 80$ so that changes in skin tone are readily discernible. This is also a requirement for areas around a sauna. The recommended light colour is warm white.

Massage room

The illuminance required in a massage room is the same as for therapy rooms in a healthcare facility: 300 lx. This lighting level is primarily needed for cleaning operations. For the massage itself, there is no need for bright light. Dimmed general lighting is enough for a massage session; accent lighting is a possible alternative. The recommended light colour is warm white but coloured accent lighting is an option.

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Showers and lavatories

Hygiene is a prime requirement in showers and lavatories. Although the relevant standards stipulate a minimum of 100 lx illuminance, 300 lx is recommended for cleaning operations. This avoids any impression of lack of cleanliness.

As in all damp interiors, luminaires installed in showers and lavatories need to be designed to a higher degree of protection – at least IP X4 (protection against spraywater). Where shower heads in the wet zone of shower rooms are not mounted in fixed positions, an even higher degree of protection – IP X5 (protection against jets of water) – is required. In all cases, luminaires may only be operated here on protective extra-low voltages up to 12 Volts.

Lamps need a colour rendering index of $R_a \geq 80$ to reproduce all colours. Fluorescent and compact fluorescent lamps meet this requirement. Recommended light colour: warm white. In lavatories, a presence detector makes for greater convenience and conserves energy at the same time.

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Mirror lighting

Two luminaires are needed to ensure shadow-free reflection of a face. They must be mounted on either side of the mirror. For large mirrors, this side-lighting can be usefully supplemented by luminaires above the mirror. All luminaires should feature frontal shielding for glare-free lighting.

[50] Sunning indoors: The solarium cabins are adjacent to the pool area

[51] Hygiene is important in showers and lavatories. 300 lx illuminance is the minimum recommended for cleaning operations.

[52] Coloured light helps us relax. Here, the entire room is plunged into a sea of changing colours generated by RGB (red, green, blue) LEDs

Entrances

Entrances make a crucial first impression on spectators. But athletes, of course, like a friendly welcome too. So the lighting should be designed with this in mind. Its cheerful light should also encompass waiting areas.

At ticket dispensers, additional vertical illuminance makes information on monitors and displays easier to read.

Entrance area lighting facilitates orientation, dividing large open areas into sections and directing the way to pay points, spectator stands and toilets. Route-marker systems can also be installed; modern LED (Light Emitting Diode) systems are a particularly energy-efficient choice. LEDs have another advantage: they produce not only white but also coloured light, even RGB mixes if required.

Communication routes and staircases

Staircase lighting and lighting for corridors and passageways needs to help make communication routes safe. Generally speaking, 100 lx is sufficient for orientation. However, this minimum requirement stipulated in standards is based on the assumption that communication routes are frequently used and therefore familiar.

For visitors, 200 lx is more comfortable and safer. This is because the higher illuminance makes potential tripping hazards easier to recognise. It also enables people to gauge more accurately what other persons are likely to do.

Care should also be taken to ensure good uniformity of lighting on communication routes. Ceiling or wall luminaires with compact fluorescent lamps or tubular fluorescent lamps are used for this application.

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They are both particularly energy-efficient. The use of presence detectors to switch lights on and off automatically helps conserve energy and cut costs.

Accentuating lighting in corridors, e.g. wall-washing, raises vertical illuminance and thus enhances visual comfort. Staircases are correctly illuminated from the landing above to create the short soft shadows needed to enable each tread to be clearly distinguished from the one below.

[53] Lighting at an entrance makes for a friendly welcome and helps visitors get their bearings.

[54+55] Uniform, cheerful light accompanies visitors along communication routes. 100 lx illuminance is enough for orientation but 200 lx is more comfortable and safer for visitors who do not know their way around.

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Catering

Lighting for bistros and cafeterias needs to be planned and designed to suit the architecture and the furnishings. The primary design objective is to make guests feel comfortable. To achieve this, the lighting needs to keep the service area low-key. Extra light, however, can be usefully provided to emphasize the tables.

For small rooms, a limited number of luminaires of the same type are normally enough. In larger rooms, ceiling luminaires or spots and luminaires on power track provide the general lighting required. A second or third lighting system, e.g. pendant luminaires or wallwashers assigned to tables, can then be used to furnish accentuating light.

At a bar, a combination of accent and indirect lighting is the right choice. The recommended light colour for all catering establishments is warm white. Lamps with a colour rendering index of $R_a \geq 80$ ensure that food and drinks look appetising.

At tills with monitors, care must be taken to ensure that the visual task is not impeded by disturbing reflections. Keyboard or keypad must not be too dark; if necessary, supplementary lighting should be provided. Where a growing number of incorrect entries are noted, the lighting situation should always be considered as a possible contributing factor.

[56] The lighting concept of a catering establishment is a major factor determining whether guests feel comfortable. It should be coordinated with the architecture and furnishings.

[57] From outside, the restaurant on the bathing lake is an eye-catcher. Its lighting concept uses luminaires for high rooms to produce a relatively high lighting level. However, the light can be dimmed.

[58] Catering for fans at a soccer stadium: to prevent interference with the view of the screens, lighting must not dazzle.

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Lamps

The two pages overleaf (58/59) show lamps that are suitable for sports and leisure facility lighting. They can be supplemented or substituted by LEDs. Fig. 59 on the page opposite shows examples.

The table beneath the images on pages 58/59 sets out the performance data of the individual lamps. Precise values for each available rating class and other specifications are contained in manufacturers' catalogues.

As a general rule, lamps are selected first, suitable luminaires second. Lamps need to meet the requirements of the relevant lighting task in terms of quality of light (colour, colour rendering), mode of operation (times, starting characteristics, failure mode, etc) and energy efficiency.

Technical terms

Lamps need electrical energy (electricity) to operate. They thus consume electrical power in Watts (W), see **"Power rating"** in the table. Multiplying this by the lamp's service life in hours indicates its energy consumption (kWh). The operation of discharge lamps (lamps 1 to 19) requires ballasts und, in the case of some models, igniters, which consume additional electricity and thus increase the rate of energy consumption. These control gear losses are not taken into account in the table. Efficient ballasts and operating modes improve a lighting system's energy and economic efficiency. The EU directive on energy-using products (EuP) and its ordinances require efficient operation.

Luminous flux is the rate at which light is emitted by a lamp in all directions. It is measured in lumens (lm). **Luminous efficacy** is the measure of a lamp's energy efficiency. It is the luminous flux of a lamp in relation to its power rating and is expressed in lumens per Watt (lm/W). The higher the lm/W ratio, the more efficiently a lamp turns the energy it consumes into light. In the case of some lamp types, EU directives set out a minimum requirement for luminous efficacy to limit energy consumption and thus make a contribution to climate protection.

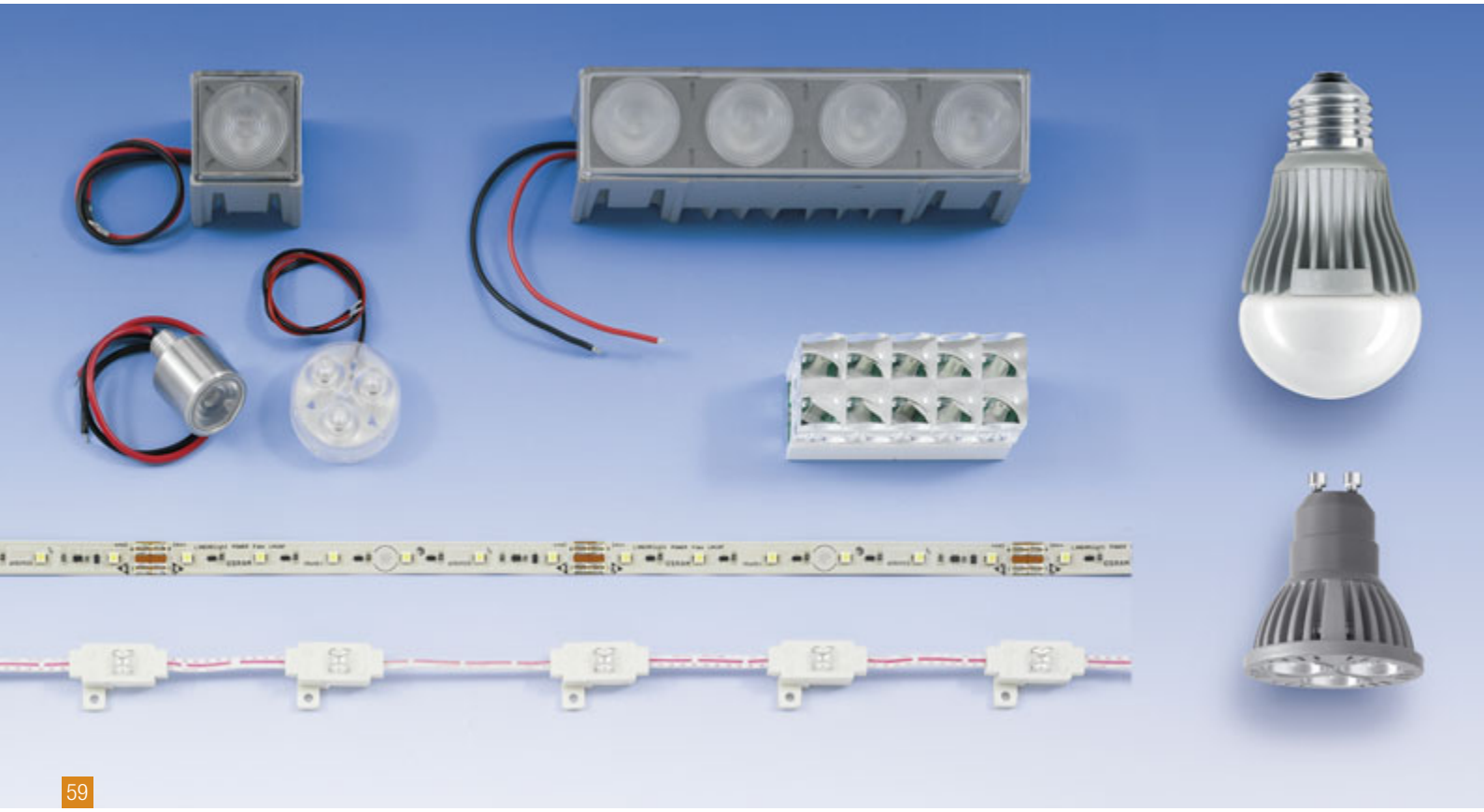
Lamps have different **light colours**, which are determined by the spectral composition of the light they produce. If the main visible radiation is in the red range, the light is classed as warm white (ww); where blue content is higher, it is described as neutral white (nw) or daylight white (dw). Light colour within these classes is defined more precisely by colour temperature in degrees Kelvin.

The colour rendering properties of lamps are defined by the **colour rendering index R_a**, which is based on a number of specific colours. The highest R_a value possible is 100, which means perfect colour rendering. The lower a lamp's R_a value, the poorer its colour rendering properties and thus the more inferior the quality of light.

The amount of light emitted by a fluorescent or high-pressure discharge lamp decreases over the course of its **service life**. A drop in luminous flux is likely earlier where a conventional ballast is used rather than an electronic one. Information about the "Life behaviour of discharge lamps for general lighting" is available from the German Electrical and Electronic Manufacturers' Association – ZVEI (www.zvei.org).

Important note: Discharge lamps have different ignition and starting characteristics. Some – mostly double-ended – lamp types permit hot re-ignition, others need to cool for a few minutes before they can start again.

The **base** provides the mechanical connection with the luminaire. It supplies power to the lamp and facilitates positioning. The better the light can be controlled by the luminaire, the greater its light output ratio. Basically, there are two kinds of lamp base: screw bases, e.g. all E bases, and plug-in bases. Base types are defined by one or more letters and a sequence of numerals.



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Light emitting diodes

LEDs are semiconductors that give off light when electronically excited at a very low voltage. All semiconductors are encased in a housing to protect them from environmental influence. There are individual LEDs, LED modules, LED systems (luminaire with LEDs) and LED lamps on the market. Unlike conventional light sources, LEDs produce monochromatic coloured light. White light of different colour temperatures (neutral white, warm white) is obtained by luminescence conversion – directing the monochromatic light of a blue LED through a yellow converter material such as phosphor.

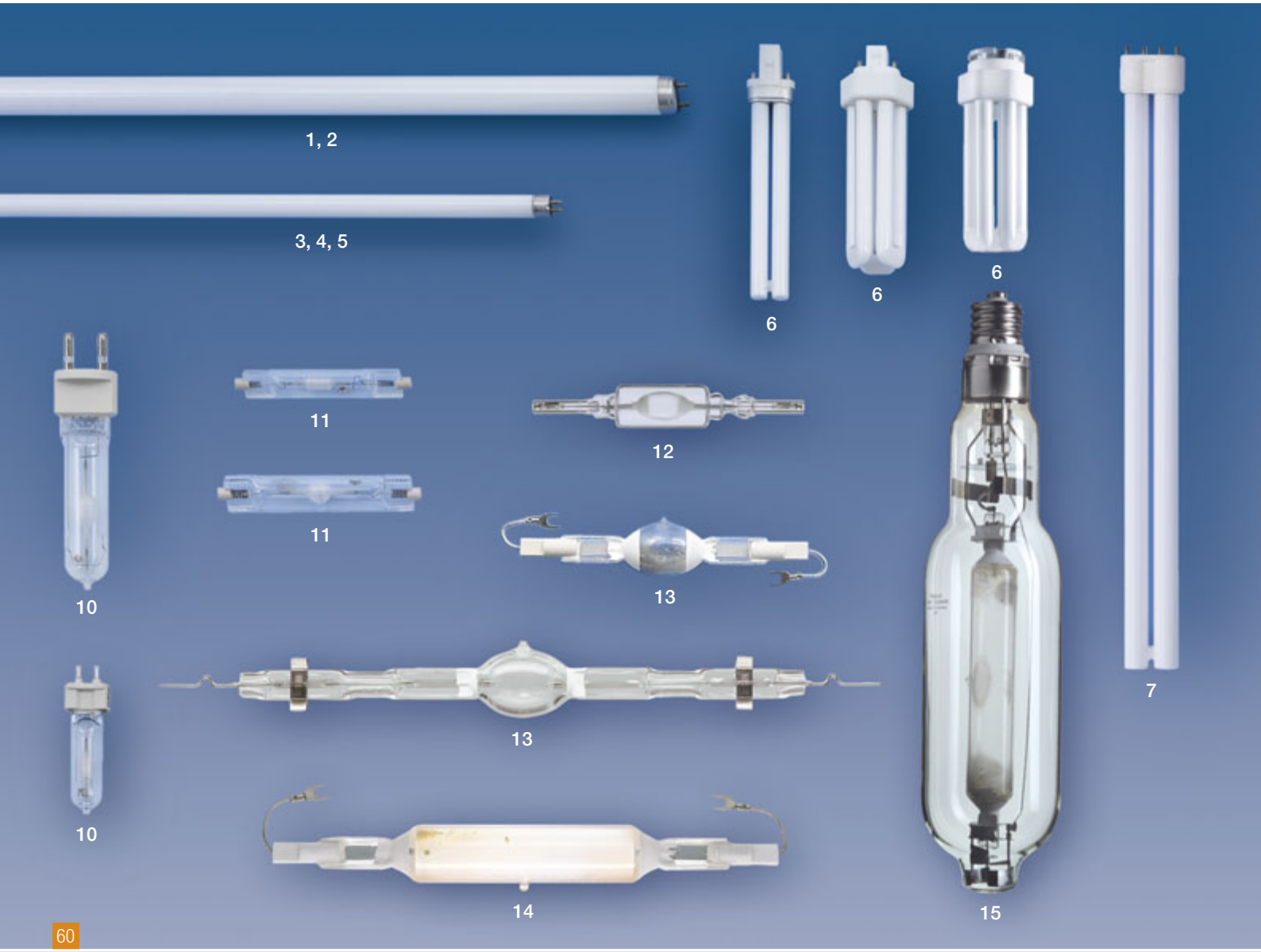
Coloured LEDs started out as status and signal indicators in electronic equipment. Then they found applications in orientation and special effect lighting. Today, white LEDs are in increasingly widespread use as a source of “viewing light”. Because LED light contains no ultraviolet (UV) or infrared (IR) radiation, it is particularly suitable for lighting where light- and heat-sensitive materials are present.

LEDs are dimmable. Appropriate pulsing (pulse-width modulation – PWM) produces a linear reduction in light output without affecting light colour. The diodes have an extremely long life, ranging up to 50,000 operating hours. Failure is rare. Unlike high quality LEDs, however, cheap products lose their brightness relatively quickly.

LEDs are fairly easy to control electronically. Apart from dimming, they can be harnessed to deliver a dynamic sequence of changing colours. The RGB colour model, in which red, green and blue light are mixed in various ways, enables millions of different colours to be reproduced. Another function of lighting control is to realise pre-programmed lighting scenes.

More information about LEDs is contained in the booklet licht.wissen 17 published by the industry association licht.de (www.licht.de).

[59] Light emitting diodes (LEDs): Individual LEDs (not illustrated) are not very widespread; modules – like the ones shown here – are more commonly used. The two LED lamps on the right are direct replacements for screw base incandescent lamps (top) and pin base halogen reflector lamps (bottom).



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		Three band ∅ 26 mm	Three band longlife ∅ 26 mm	Three band ∅ 16 mm high luminous efficacy	Three band ∅ 16 mm high luminous flux	Three band amalgam ∅ 16 mm high luminous flux	Three band 1-, 2- oder 3-tube lamp[3)4)]	Three band elongated[4)]	Three band 4-tube lamp and square design	Three band 3- or 4-tube lamp
Lamp type		1	2	3	4	5	6	7	8	9
Characteristics	Lamp category	Linear fluorescent lamps					Compact fluorescent lamps			
Power rating (Watts)	from	18	18	14	24	24	5	18	16	60
	to	58	58	35	80	120	70	80[5)]	36	120
Luminous flux (lumens	from	1,350	1,350	1,300	1,900	1,850	250	1,200	1,100	4,000
	to	5,200	5,200	3,650	7,000	8,850	5,200	6,000	2,800	9,000
Luminous efficacy (lumens/Watt)	from	75[1)]	75[1)]	79 (93)[2)]	69 (84)[2)]	72 (76)[2)]	50	67	61	67
	to	90[1)]	90[1)]	93 (104)[2)]	88 (99)[2)]	90 (93)[2)]	82	88	78	75
Light colour		ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw
Colour rendering index R_a (in some cases as range)		80 – 85	80 – 85	80 – 85	80 – 85	80 – 89	80 – 85	80 – 85	80 – 85	80 – 85
Life (in hours)	from	15,000	40,000	20,000	20,000	18,000	5,000	9,000	5,000	
	to	20,000	90,000	24,000	24,000	24,000	15,000	15,000	10,000	20,000
Base		G13	G13	G5	G5	G5;	G23; G24; 2G7; GX24 GR14q	2G11; 2GX11	2G10; GR8; GR10q	2G8-1

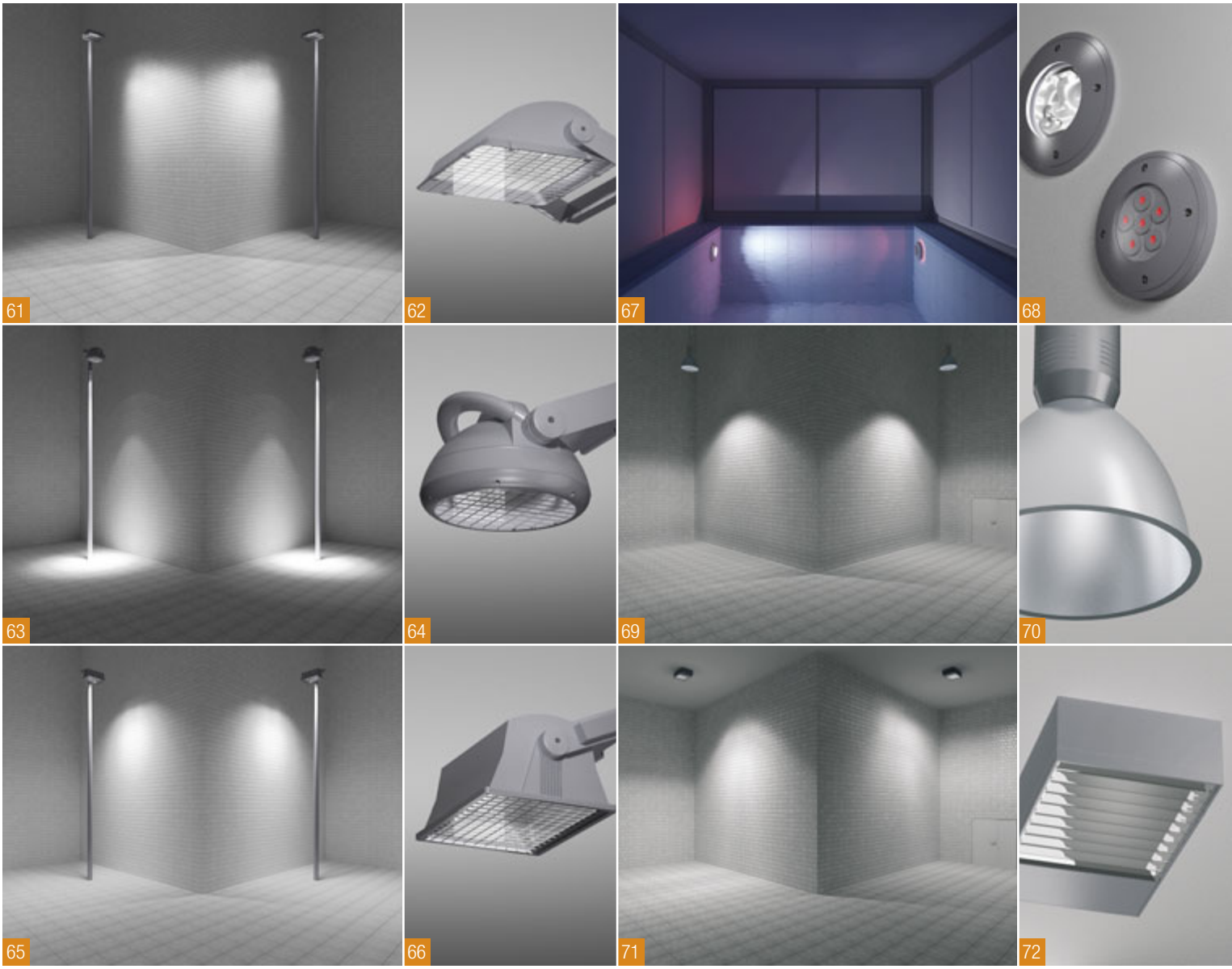
Lamps

Table footnotes

[1] Where lamps are EB-operated, luminous efficacy increases to 81–100 lm/W. The power input decreases from 18 W to 16 W, from 36 W to 32 W and from 58 W to 50 W
[2] High values at 35° ambient temperature
[3] Lamps 6.3 and 9 for wider temperature range
[4] Lamps 6.2 and 7 also as special models for wider temperature range
[5] 40 W and 55 W only with EB
[6] Also available in other designs

ww = warm white
colour temperature below 3,300 K
nw = neutral white
colour temperature 3,300 to 5,300 K
tw = daylight white
colour temperature over 5,300 K

Single ended with ceramic burner	Double ended with ceramic burner	Double ended with ceramic burner	Double ended with ceramic burner short arc	Double ended with ceramic burner long arc	Tubular (T) quartz	Ellipsoid (E) quartz	T or E with ceramic burner	Ellipsoid	Tubular	With screw base, incandescent lamp-shaped[6]	Double ended
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
			Metal halide lamps					**HP sodium**		**Halogen lamps**	
20 400	70 250	70 400	1,000 2,000	1,000 2,000	70 2,000	70 1,000	70 250	50 1,000	50 1,000	18 205	48 2,000
1,600 41,500	5,100 25,000	5,500 36,000	90,000 220,000	90,000 230,000	5,800 240,000	4,700 110,000	4,700 26,000	3,500 128,000	4,400 130,000	220 4,200	700 44,000
80 106	73 104	79 90	90 110	90 107	83 120	74 110	80 104	63 139	70 150	12 20	14 22
ww, nw	ww, nw	ww, nw, dw	nw, dw	nw, dw	ww, nw, dw	ww, nw, dw	ww, nw	ww	ww	ww	ww
80 – 96	75 – 95	76 – 93	80 – 90	65-85	65-93	65 – 90	80 – 95	25, 65	25, 65	100	100
9,000 12,000	9,000 12,000	9,000 12,000	4,000 6,000	8,000 12,000	6,000 12,000	9,000 13,000	12,000 32,000	18,000 32,000	18,000 32,000	1,000 2,000	1,500 2,000
G12; G22; GU6,5; GU8,5; GX8,5; PGJ5	Fc2 RX7s	RX7s; Fc2	Kabel, K12s	Kabel K12s	G12; E40	E27 E40	E27 E40	E27 E40	E27 E40	E27 E14	R7s



Luminaires

The term “luminaire” is used to denote the entire light fitting, including all components required to affix, operate and protect the lamp. The luminaire provides protection for the lamp, distributes and directs its light and prevents it from dazzling.

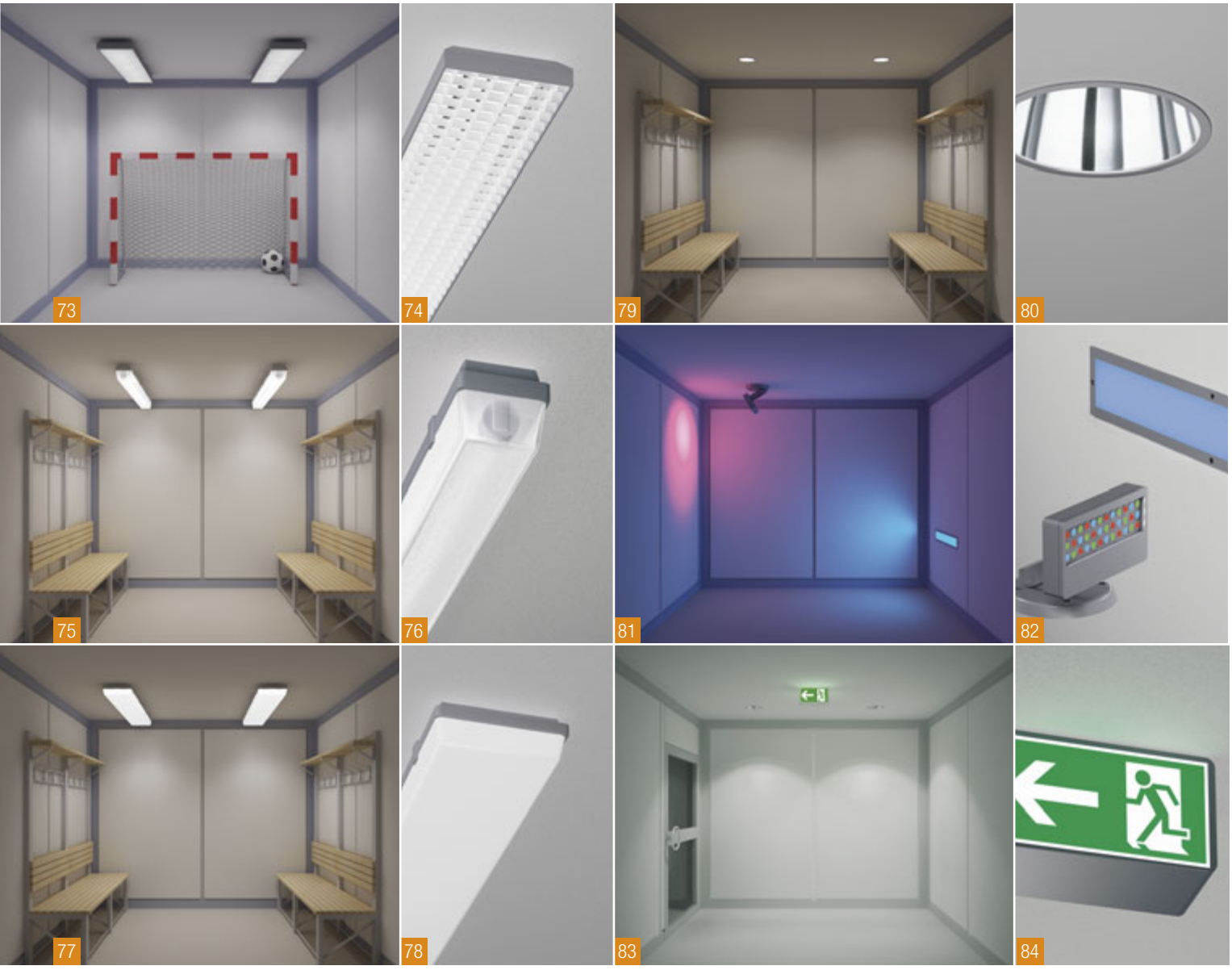
Luminaire selection is determined by the lighting requirements of the lighting task, the choice of lamps and the mechanical and electrical requirements that need to be met. Room architecture and design intent also play a role.

The degree of protection to which a luminaire is designed guarantees its operational reliability. Degrees of protection are indicated by IP codes (Ingress Protection) consisting of two numerals. The first numeral (1 to 6) describes the degree of protection against solid foreign bodies, the second (1 to 8) indicates protection against moisture. The higher degrees of protection also indicate conformity to the degrees lower down the scale. Where a capital “X” appears in place of one of the numerals, it means the luminaire has not been tested for that form of protection.

Impact resistance

Luminaires for sports halls need to be impact-resistant in conformity with DIN VDE 0710-13. This means that if they are struck by a ball, they must resist damage that could cause luminaire parts to fall to the ground.

The stylised paired images on these two pages, which are not to scale, show a selection of typical luminaires for sports and leisure facilities. In each pair, the image on the left shows the radiation characteristics and lighting effect of the luminaire depicted in the image on the right.



[61 + 62] Floodlight with asymmetrical beam for outdoor sports facilities – floods of this type for indoor facilities look identical, only smaller.

[63 + 64] Floodlight, round, symmetrical beam, for outdoor sports facilities

[65 + 66] Floodlight, rectangular, symmetrical beam, for outdoor sports facilities

[67 + 68] Swimming pool luminaires for special low-voltage halogen lamps (left) and for LEDs (right)

[69 + 70] High bay reflector luminaire, axially symmetrical beam

[71 + 72] High bay downlighter, symmetrical (left) and asymmetrical (right) beam

[73 + 74] Impact-resistant louver luminaire

[75 + 76] Diffuser luminaire for damp interiors

[77 + 78] Opal diffuser luminaire

[79 + 80] Downlights, symmetrical beam

[81 + 82] Accent luminaire (left) and orientation luminaire (right) with LEDs for coloured lighting

[83 + 84] Escape sign luminaire

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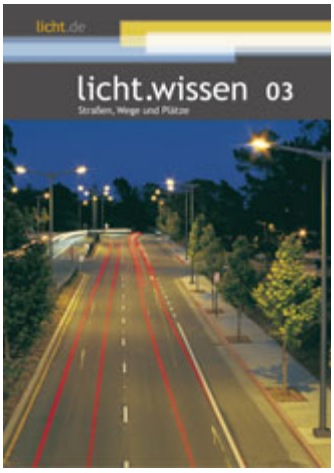

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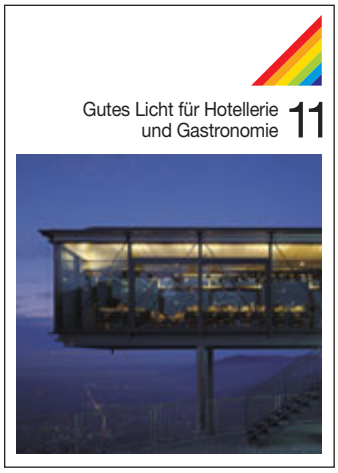

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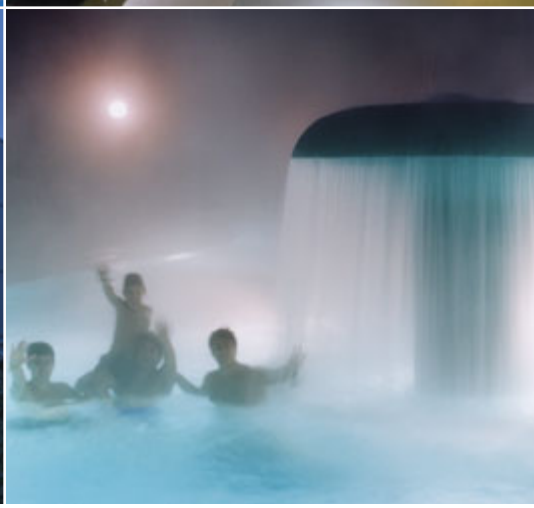

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