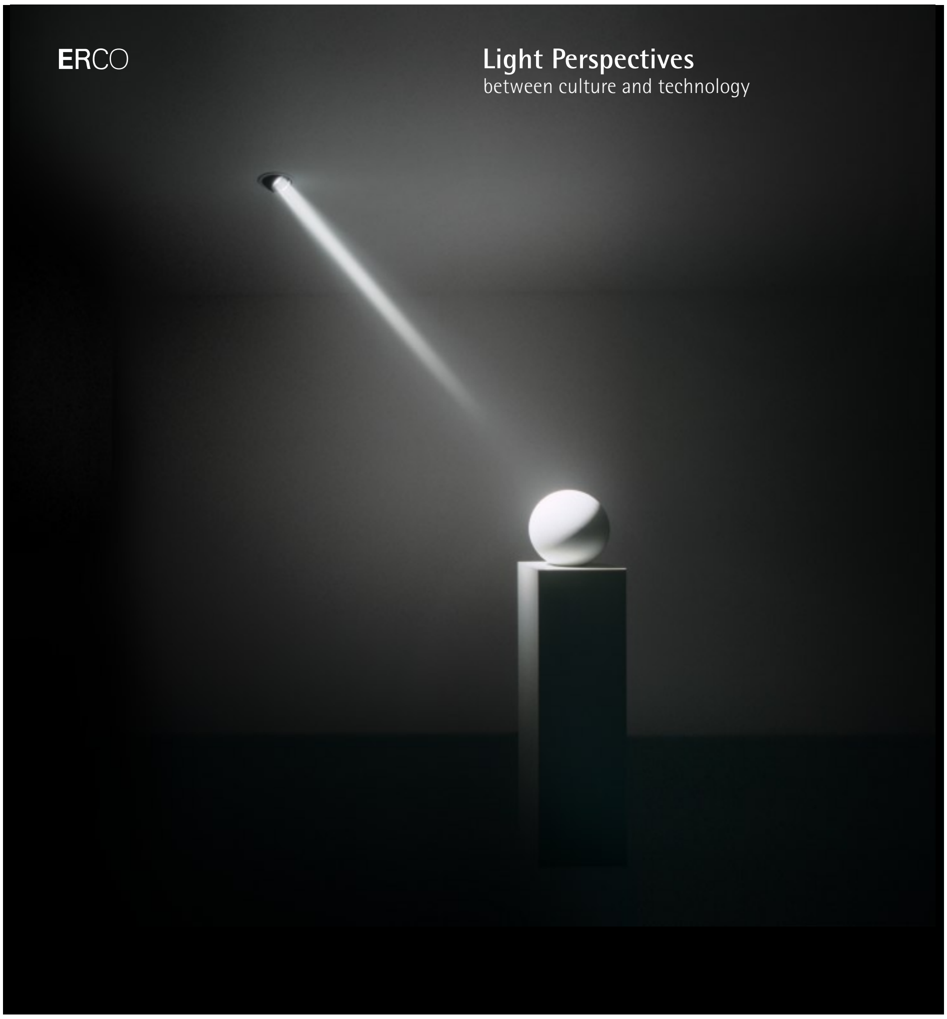
Media details
Light Perspectives reference book



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About this book
What are the intrinsic qualities of light, and how are the techniques and design approaches implemented in architecture? How are abstract lighting concepts conveyed, and how far is our perception of light rooted in the biological and cultural history of human evolution? This book endeavours to identify terms and standards which relate to qualities in architectural lighting. It uses this identification to promote communication and aid dialogue between designers and engineers, building owners and planners, professionals and laymen. The 21 chapters are arranged in three sections covering the actual qualities of light, the relationship between light and space and, finally, the dimension of light as it relates to culture. In each of the chapters, paired terms explore the respective design dimension of light. Using texts, photos, computer graphics and drawings, the team of authors investigates each pair of terms – beginning with the original cultural and historical context, moving onto didactic material on perception, lighting design and lighting technology and concluding with case studies in virtual architectural situations.

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Contents

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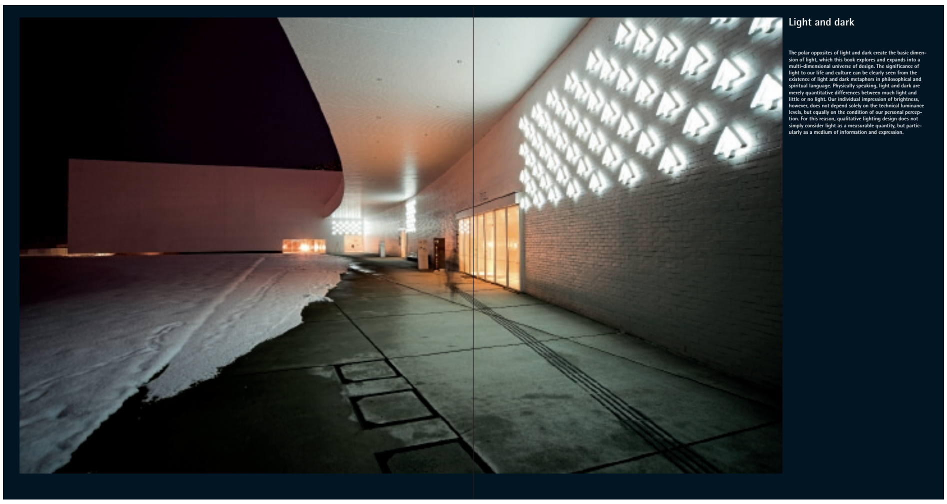
Structure of chapters

The 21 chapters of the book all share a uniform structure consisting of introduction, essay, teaching and simulation.

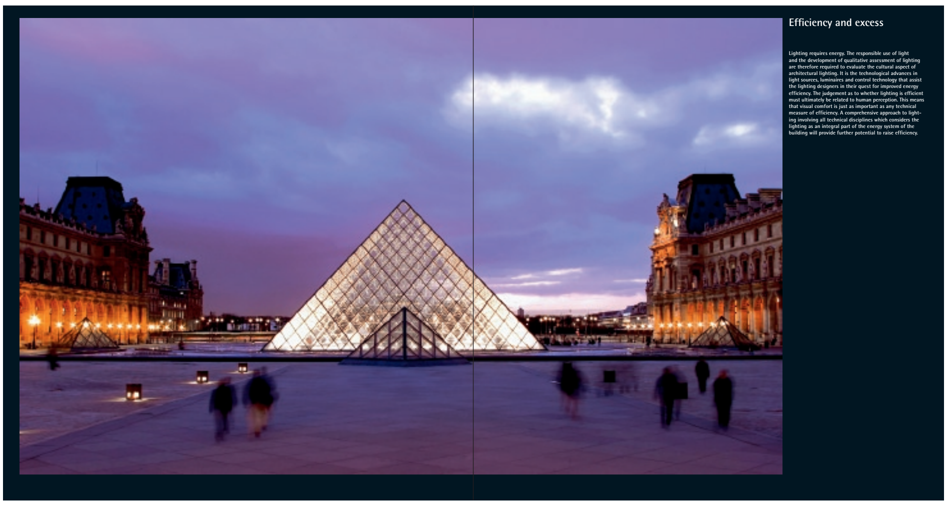
Introduction

A large-format photograph of an actual lighting application illustrates the subject area to be explored by the respective paired terms. The introductory text summarises the most important theses and contents for the twin terminology.



10 Light and dark

44 Radiance and illumination



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Essay

Using insights gained from the fields of culture, natural science, history or literature, this text approaches the subject area with a journalistic, essay-type style. This provides a variety of starting points and associations, ensuring that the following teaching pages are put in their proper context.

Light and dark
Between two poles there exists a world of design possibilities

12 Light and dark

Radiance and illumination
From beautiful light to magical effect

46 Radiance and illumination

Efficiency and excess
Light between function, luxury and culture

194 Efficiency and excess

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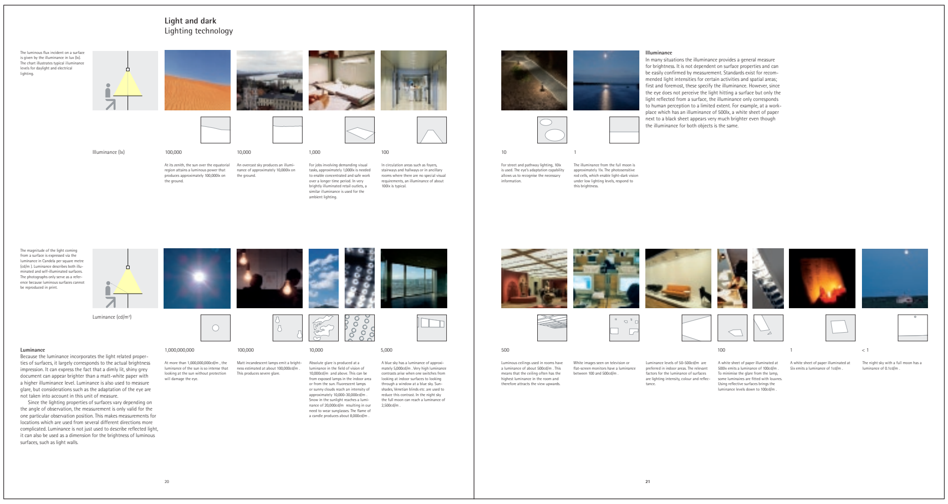
Teaching
The didactic part of a chapter explores the subject area more comprehensively with regards to perception, lighting technology and lighting design. Here, texts, photos, drawings and diagrams combine to optimally put across the facts, giving particular emphasis to visual presentation – as befits the key theme of light. A recurrent device here is the use of charts and series of images to add specific content to all the intermediate stages in-between the paired terms.



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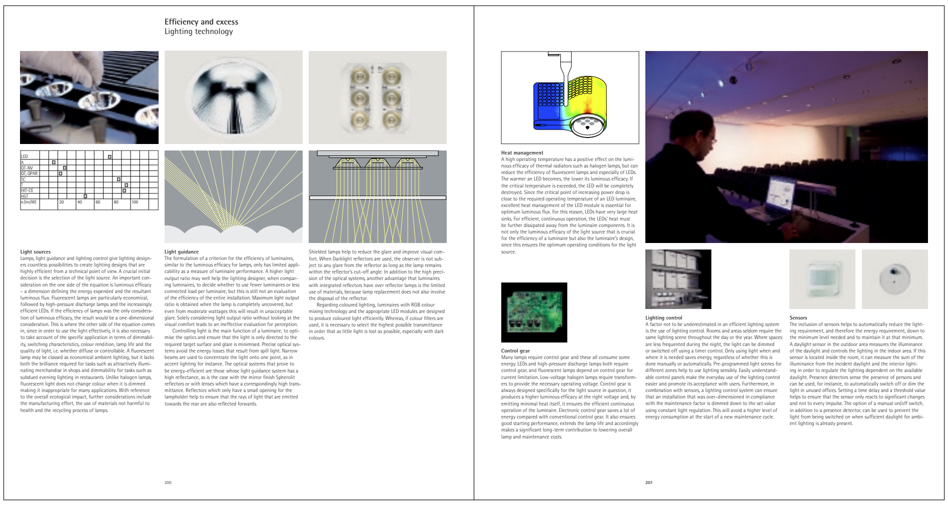
50 Radiance and illumination



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Simulation
The facts and theories previously expounded in the chapter are put to the test in an application example in the simulation section. A virtual architectural situation, simulated in photographic quality, is shown with different variations in the lighting commensurate with the theme of the chapter. In some cases, opposite extremes are placed alongside each other in order to vividly illustrate the respective lighting dimension; in other cases, preferences for certain lighting concepts are presented and explained. The simulations are all generated using the photometric data of real ERCO lighting tools.

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Warm and cold

The twin terms "warm–cold" convey the perceived temperature of light and colour. Misunderstandings can arise because the scale used for colour temperature contradicts what common sense would suggest. Bluish daylight white has a higher colour temperature than reddish warm white. However, with terms and definitions defined, adding contrasts in colour temperature proves to be a simple design concept in architectural lighting.

Warm and cold
Colour temperature – a subtle design concept

Samediggi in Karasjok, Norway: the illuminated building promises protection and warmth in the frosty winter landscape.

In office buildings, such as the ING Bank headquarters near Amsterdam, light sources with different colour temperature are used to differentiate prestigious areas from office space.

The cool, hi-tech architecture of this Berlin advertising agency is aptly complemented by a cool lighting atmosphere with turquoise accents.

The dimmed light of halogen lamps in recessed luminaires with high cut-off angles combines well with the candle-light to complement the classic, cosy atmosphere of the bar at the Faena Hotel, Buenos Aires.

At first glance, transferring the terms of physical temperature, "warm" and "cold", over to the qualities of light appears simple and logical. Yet this transfer often results in misunderstandings, especially when lighting concepts are being discussed between experts and lay people. This is because "warm" and "cold" can take on quite different meanings when referring to the phenomena of light and colour. Colour theorist Johannes Itten, for instance, talks of the warm-cold contrast of colours. Then there are warm white lamps as opposed to daylight white. One talks of "colour temperature", but, contrary to common sense, this is higher with "cool" white hues! Photographers refer to "cold" flashlight and the "hot" light of an incandescent lamp. They have to compensate using laborious technical measures, filters or manual white fader – something which the human eye performs fully automatically in a process known as chromatic adaptation. Behind all these terms are the physical and perceptual psychological effects that have been used in art and design for centuries – starting with artistic disciplines such as painting and now in architectural lighting.

Cold blue, warm red?

When designers talk of warm and cold colours they are usually referring to the warm-cold contrast – a design concept known about for ages and described by, amongst others, the painter and art theorist Johannes Itten (1888–1967) in his book, "The Art of Color". Itten states that we intuitively ascribe a "cold" quality to bluish colours and call reddish hues "warm". One can of course speculate as to how the link between these perceptual qualities may have occurred – certainly various impressions would have played a role here, such as the reddish hues of a warm, blushing face compared with the bluish tone of the skin or lips of people when freezing cold. Whatever the case, it has been empirically shown that rooms painted blue are actually perceived to be colder than those painted red. Even our estimation of distance is influenced by warmer or cooler hues. Warmer colours appear nearer and cooler tones seem further away. Renaissance painters used this phenomenon in what they called "colour perspective", painting the background in blue-green tones to distance it from the warm hues of the foreground. This trick works because the different wavelengths of red and blue light mean that objects of those colours are actually imaged by different receptors in the eye.

In the more subtle range of white tones, this warm-cold classification originating from art theory now finds expression in the form of the name "warm white", used for the colour of light from certain fluorescent lamps. It describes a more reddish tone of white in contrast to "neutral white" or the even more bluish "daylight white". In the good old days of analogue photography, photographers also liked to talk of the "hot" light of photo lamps – that really did warm up the studio – as opposed to the "cold" daylight-like light of electric flash bulbs. Confusion often arises when these colloquial categories are used alongside the technically correct physics terminology for specifying colour temperature in Kelvin. Paradoxically, the colour temperature of an incandescent lamp or a warm white fluorescent lamp is lower than that of a daylight white light source.

When the black body glows

Physicists define colour temperature using an idealised object known as "black body". A black body completely absorbs all electromagnetic radiation, such as light, of any wavelength. It is also an ideal source of thermal radiation, whereby its spectrum is dependent purely on its temperature. As a result, this temperature therefore defines the colour temperature in Kelvin. The filament of an incandescent lamp approximates quite closely to this abstract concept. It is dark and colourless when cold. It starts to glow, dark red at first, as the temperature increases and finally radiates a warm white hue when the nominal voltage is reached. As the voltage applied is increased further, the colour temperature of the incandescent lamp shifts towards blue until the filament eventually melts. When this is shown in the CIE chromaticity diagram, the black-body radiator can be seen to follow "Planck's curve". This traces the colour loci from extremely warm-toned white to extremely blue white. This curve is used as a reference for the colour temperature specifications of light sources.

Although, with flames and incandescent lamps, the colour temperature does in fact directly correlate to the temperature of the light source, this is not the case with light sources such as discharge lamps or LEDs. The narrow-band radiation of the gas discharge or electro-luminescence is converted via a mixture of luminescent substances into visible light, but without a continuous spectrum. The composition of the luminescent substances determines the colour temperature resulting in a mixed white tone. A problem can occur in our psychological perception of different light sources as they are dimmed. Because we are conditioned by the natural progression of daylight which is characterised by a red shift with the decreasing brightness of evening, we therefore perceive the analogous effect of red shift when dimming an incandescent lamp as pleasant an natural. By contrast, fluorescent light maintains a virtually constant colour temperature as it is dimmed and is quickly perceived as cold and unnatural.

Creating atmosphere, adding contrasts

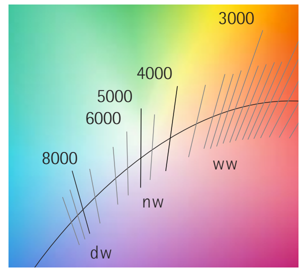
In architectural lighting, these and other effects of perception can be used for design purposes in conjunction with different colour temperatures. In principle, the choice of the dominating colour of light can basically dictate the atmosphere of a room, ranging from cool, businesslike and motivational to warm, cosy and calming. However, when looking at architectural examples from various regions of the world or browsing through back copies of interior design magazines, it soon becomes clear that the link between warm or cool lighting/colour moods and the associated preferences and values is also greatly dependent on fashions or cultural background.

The use of colour temperature is a more subtle design technique because, as mentioned above, the human eye has the quite remarkable ability to perform chromatic adaptation. This means that, after a short period of adapting to lighting at different colour temperatures, the eye perceives body colours such as a white sheet of paper as constant. Conversely, photographic films – and even digital cameras when the automatic white fading is deactivated – will soon reveal whether the lighting has different colour temperatures. This is why special emulsions or intricate filters were needed with films to achieve natural-looking colours in the image. Most digital cameras today allow the user to adjust the white point manually, either to categories of light or even to Kelvin values.

The human eye's ability to adapt means that if a lighting design using light of a homogenous colour temperature is to be consciously noticed – not just as a subliminal atmospheric component – then exceptionally cool or warm white hues must be used. The contrast between warm-toned and cooler lighting is far more easily perceived, making it useable for design purposes. By specifically accentuating exhibits in cool tones, they can be distinguished from architectural elements illuminated in warm tones, or vice versa. On the other hand, it is immediately noticeable when lamps of different light colours are accidentally mixed up during routine maintenance. The colour of light can emphasise and accentuate the properties of surfaces or differentiate spatial zones. Furthermore, changing light colours in the same room can be used to represent daytime or evening moods. This can be implemented with the appropriate technology, i.e. by using different components of light, such as fluorescent light in daylight white plus halogen light or using luminaires with variable colour temperature, as are now becoming increasingly available.

However, when using this design technique, the lighting designer should always bear in mind that the colour temperature of a light source is not directly related to its colour rendition property – which has more to do with the spectral composition of the light. This is why, for critical applications such as in museum lighting or in the clothing trade, light sources with a high colour rendition index ($R_a > 90$) are always specified irrespective of the colour temperature in order to avoid incorrectly rendered colours.

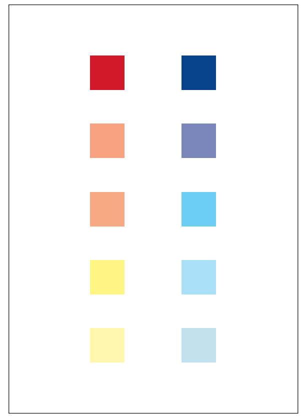
The lighting concept for the exhibition areas in the coal washing plant at the Zollverein colliery in Essen uses fluorescent light in daylight hues as indirect lighting for the ceiling. This is combined with warm-toned accents from spotlights with low-voltage halogen lamps.



Planck's curve within the CIE chromaticity diagram plots the colour locus of a black-body radiator relative to temperature, thereby defining the colour temperature of a white light source.

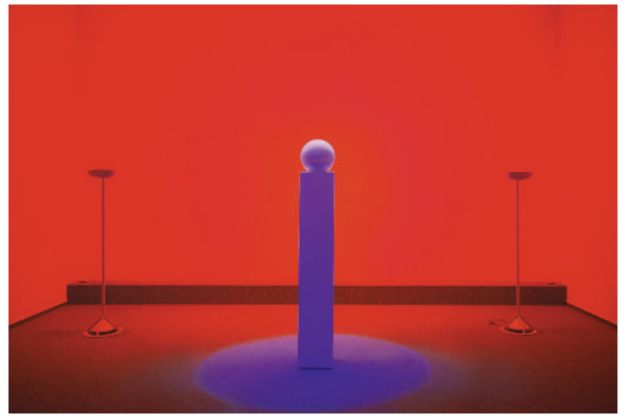
Warm and cold
Perception and lighting technology

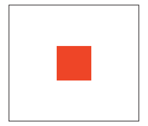
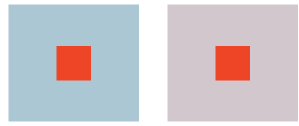

The course of the day
The colour of light, or rather the colour temperature of the daylight, is constantly changing throughout the course of the day. Since other factors such as brightness or diffusion and directed light have a much greater variation, less importance is often attached to the perception of the warm and cold colours of light. However, our perception of materials varies significantly at different colour temperatures. Whereas lighting designers cannot influence the colours of the daylight, they can actively alter the atmosphere and the appearance of materials with artificial lighting.



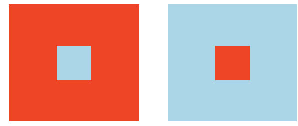
Warm-cold contrast
In the colour wheel, the warm colours with red and yellow components are arranged opposite the cold, blue hues. Both the colours of materials and the hues of light will make the observer feel cold or warm and contribute to the atmosphere of a place. Similarly, the hues of light known as warm white, neutral white or daylight white can be used to establish a warm-cold contrast and set the mood of a room.





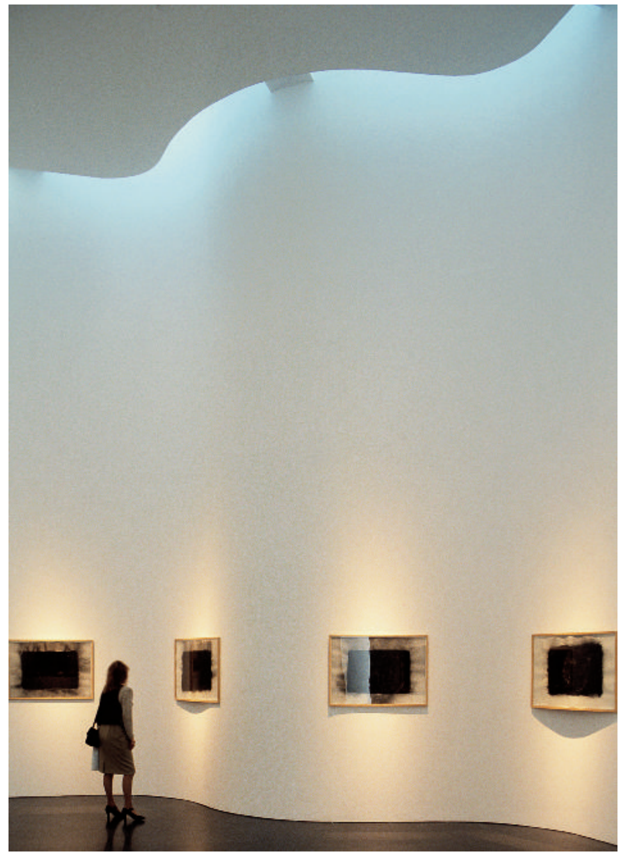
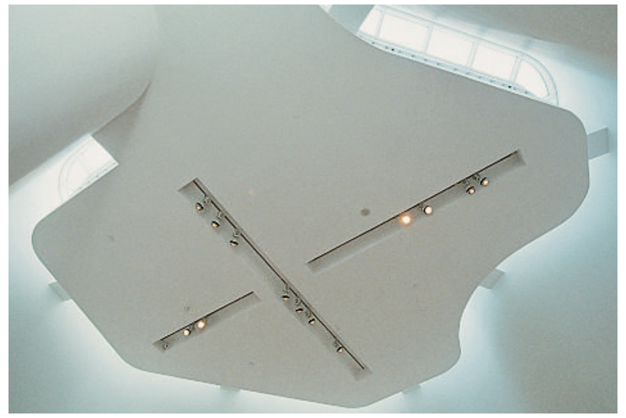



Against a coloured background a coloured area will appear more intensive than against a neutral white background. The warm-cold contrast produces a greater contradistinction than against a similar colour. A pastel-coloured background for a primary colour gives a lower contrast than more saturated background colours.



The complementary contrast of a colour that lies opposite on the colour wheel intensively increases the effect of the main colour. In terms of depth perspective, red seems to come to the fore, whereas a pale blue is associated with the horizon and the sky and recedes into the background.

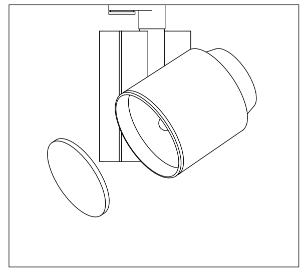
Colour effect of materials
The colour effect of materials can be intensified by choosing the right colour of light. The colour impression of warm-toned materials such as sandstone is heightened by lighting them with an appropriately warm white light colour. With cold-coloured objects, using light with a warmer colour temperature would impair the colour impression of the cool material. In everyday settings, the difference is not noticed until compared with a contrast surface under lighting of a different light colour. This is because the way we perceive differences in colours is not absolute but relative. Additionally, we also perform an unconscious adaptation process when interpreting the colour of a white shade. If we look at a warm white or daylight white wall for a long time, then we recalibrate to this as a neutral white.

During the daylight, a colour contrast is formed when the warm-coloured tungsten halogen lamps are switched on. The diffuse natural light appears bluish and creates a cool background for warm accent lighting.

Daylight and artificial light
Where daylight and artificial light are both present simultaneously, the difference between the colours of light takes on an important role. Warm colours of light, as produced by tungsten halogen lamps for instance, will produce a warm-cold contrast in the presence of daylight with a much higher colour temperature. After becoming adapted to the daylight of a blue sky and direct sunlight, a cool and diffuse ambient lighting with warm accent light will seem more natural than the other way around. When looking around a room, as the gaze wanders between zones illuminated by daylight and areas illuminated by artificial light, the convergence of the colour temperatures will reduce the contrast and create a homogenous transition. Lighting designers can determine the scope of the colour contrast by their choice of lamp or by using filters.

Daylight conversion filter
To eliminate a warm white colour of light, while simultaneously making full use of the excellent colour rendition of the thermal radiators, correction filters are available. The effect of the daylight conversion filter is to shift the warm white light to the neutral white range (i.e. to shift from 3,000K to 4,000K). This reduces the difference between daylight and artificial lighting. The colour rendition quality is maintained with the daylight conversion filter.



To reduce the colour differences between daylight and artificial lighting, the colour temperature of tungsten halogen lamps can be increased by adding a daylight conversion filter.

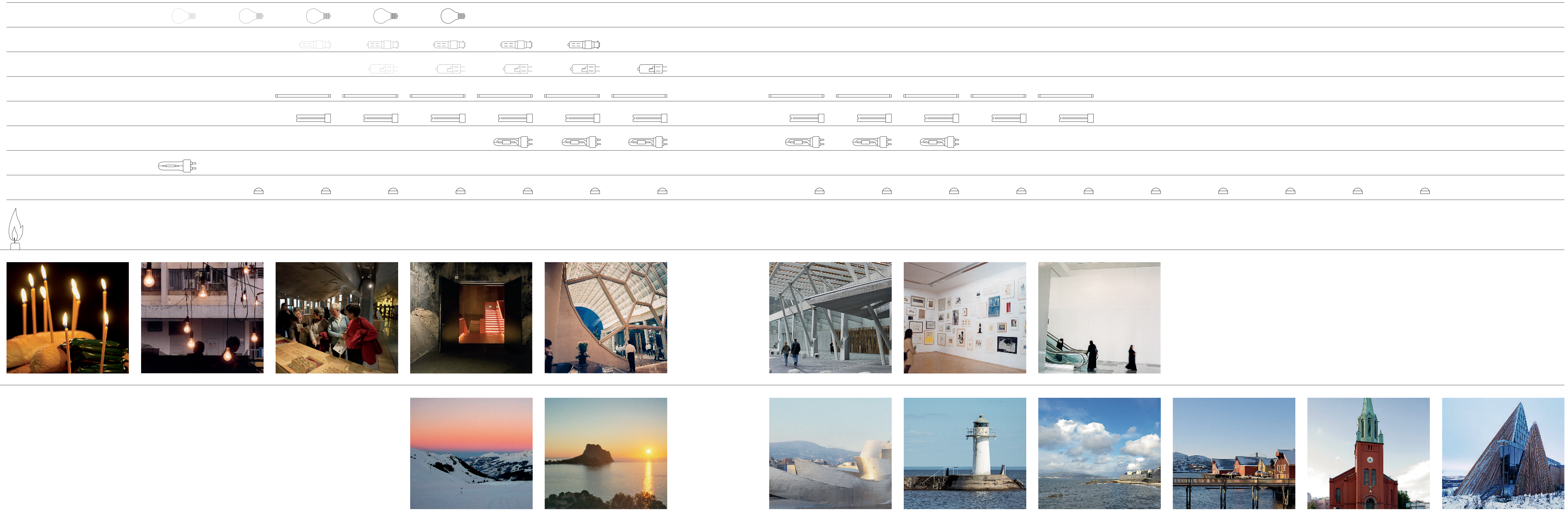
Warm and cold
Lighting technology

Incandescent lamps
Tungsten halogen lamps
Low-voltage halogen lamps
Fluorescent lamps
Compact fluorescent lamps
Metal halide lamps
High-pressure sodium vapour lamps
LEDs

Light source

Artificial lighting

Daylight



Colour temperature (K)	1,900	2,000	2,700	2,800	3,500	4,000	5,000	5,500	6,500	7,000	12,000	**Colour temperature (K)**
	Warm white					Neutral white	Daylight white					

The colour temperature is based on a "black-body radiator", also known as a "Planckian radiator", which emits a specific colour of light depending on its temperature. As a result, the colour temperature is given in Kelvin (K).

With thermal radiators such as incandescent lamps or low-voltage halogen lamps, the colour temperature is approximately the same as the actual temperature of the filament.

Dimming incandescent lamps reduces their colour temperature, the light is perceived as redder and warmer. To obtain a warmer colour of light for the same illuminance, an incandescent lamp can be replaced by a dimmed lamp of a higher wattage. Since halogen lamps have a higher filament temperature than incandescent lamps, their light appears whiter.

Fluorescent lamps, high-pressure discharge lamps and LEDs are available in different colour temperatures. When making the lamp selection, it is therefore necessary to specify the required colour temperature.

Because the eye does not perceive differences in colour temperatures linearly, a difference of 500K in the warm white range will appear to have a greater contrast than in the daylight white range. Lamp manufacturers therefore offer a wider selection of lamps for warm white colours of light than for higher colour temperatures.

To provide easily understandable classification, lamps with white light colours are categorised in three groups: warm white, neutral white and daylight white.

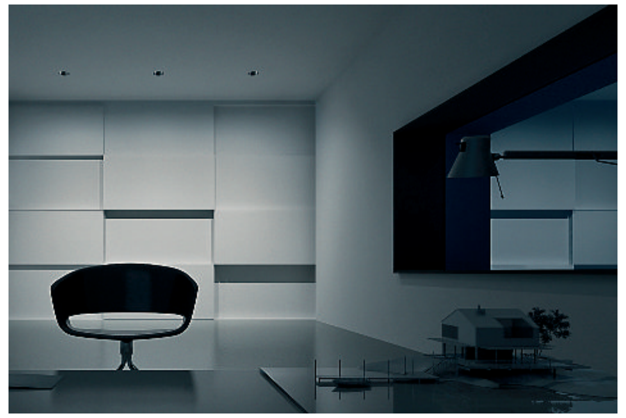
When fluorescent lamps are dimmed, their colour temperature remains constant. Compared to temperature radiators that demonstrate a colour shift towards warmer colours of light, this gives the impression that the light becomes greyer when dimmed.

The colour temperature of a clear, blue sky is over 25,000K.

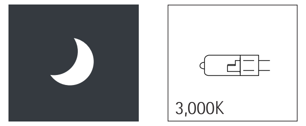
Warm and cold
Lighting concepts

The warm and cold colours of light influence the atmosphere of a space and can augment the colours of materials. Incandescent lamps provide a light of a warm colour. Light sources such as fluorescent lamps are available in different colour temperatures including neutral white or daylight white. This allows lighting concepts to be developed that follow the colour of daylight or that contrast with the lighting.

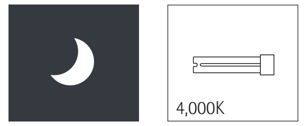
The extremely high colour temperature of daylight with a blue sky gives interiors a cool character. White surfaces appear bluish.



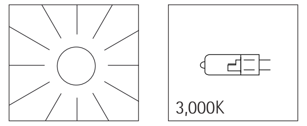
Artificial light
Incandescent lamps typically produce a warm white colour of light, which, when dimmed, changes to an even warmer hue – comparable with the setting sun which increases in orange-red colour.

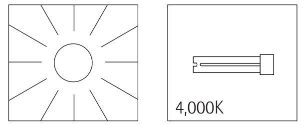


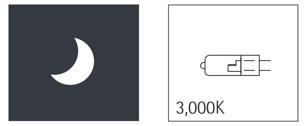
Fluorescent lamps, on the other hand, are available in different colours of light. A neutral white version produces a lighting atmosphere without the warmish yellow character. The colour of light of fluorescent lamps remains constant throughout dimming. Rooms with dimmed fluorescent lamps therefore appear rather grey in comparison with the colour change produced by incandescent lamps.

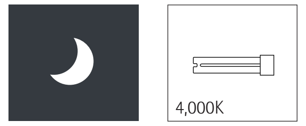


Daylight
By day, the colour of light from the artificial lighting often contrasts with the daylight and its very high and cool colour temperature. A warm-hued lighting with incandescent lamps allows a contrast of warm and cold to be built up. By contrast, fluorescent lamps with a neutral white light colour lead to a homogenous colour impression.









Material
The warm white light colour of incandescent lamps is particularly suitable for emphasising the colour of warm-toned materials such as wood or leather. This effect can be further increased using dimmed light because the colour temperature decreases with incandescent lamps when dimmed. Conversely, the cool colour of concrete or metallic objects can be shown to its advantage with neutral white or daylight white lamps.