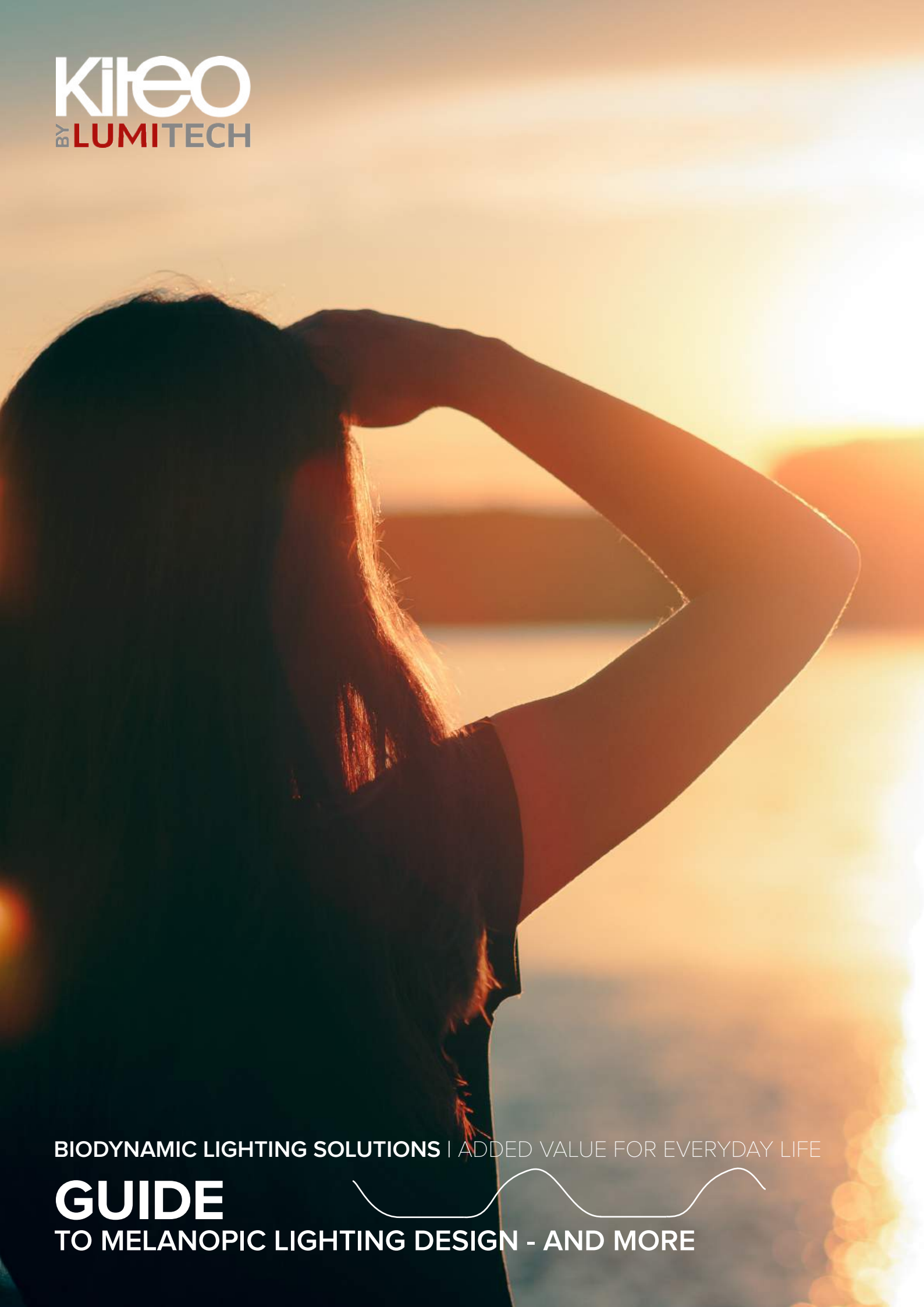


Kiteo BY LUMITECH

BIODYNAMIC LIGHTING SOLUTIONS | ADDED VALUE FOR EVERYDAY LIFE

GUIDE

TO MELANOPIC LIGHTING DESIGN - AND MORE

FOREWORD

LUMITECH & KITEO
Production and development facility in Jennersdorf, Austria

Dear lighting designers, electrical planners, architects, developers and users...

LUMITECH, which has been active in the field for over 20 years, has patented a technology (PI-LED) for implementing realistic daylight simulations indoors. Researchers and academics rely on our expertise and our products to gain new insights into the effects of light on people.

LUMITECH's PI-LED technology allows for continuously adjustable light colours from 1,800K to 16,000K, with a high CRI value to boot. Whether it's the freshness of morning, the cool light of midday or the evening glow – any light colour is possible. In addition, numerous natural colours can be simulated (dawn, sunset, etc.).

While LUMITECH supplies the global lighting industry with PI-LED components, KITEO offers ready-to-use lighting solutions based on a compact PI-LED portfolio.

The aim behind our "**Guide to melanopic lighting design – and more**" is to support lighting planners in their work. In addition to the latest research insights, the guide also provides information on DIN standards and the regulations for lighting calculations and planning.

The implementation of melanopic lighting designs depends on the "melanopic factor" of the luminaire in the respective light colour. KITEO is the first manufacturer to indicate this melanopic factor for its entire luminaire range.

This guide also contains ideas on how to design dynamic lighting solutions for users in different rooms and applications. It highlights the many possibilities of dynamic lighting design and explains the added value for users of specific applications.

The purpose of good lighting is to improve quality of life. Melanopic lighting will improve the well-being of users, allowing them to feel healthier and more energised while improving their attention span and their concentration. In addition, it can also contribute to faster recovery from illness, lower stress levels, greater relaxation and to improvements in the body's natural sleep/wake cycle.

At the same time, dynamic lighting solutions can also be used to create new and adjustable room atmospheres. In commercial applications, lighting that is fine-tuned to the specific application can really make a difference – for instance, in stores, showrooms or places of leisure such as hotels, spas or restaurants – if the right light is used at the right time.

We hope that you will enjoy browsing through this guide, which is intended to provide new and exciting insights while serving as a useful planning tool.

Dynamic greetings

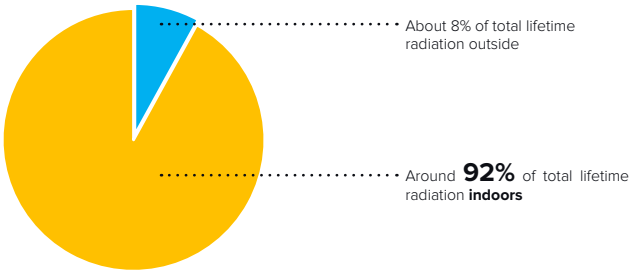
Your LUMITECH & KITEO team

Light has a noticeable effect on human health and vitality.

Sunlight is crucial for our health and well-being. Any artificial lighting solution should therefore correspond as closely as possible to the characteristics of sunlight. By simulating the spectral quality and constant changes in colour temperature of natural light, artificial lighting can have considerable positive effects on our inner clock. This results in an increased sense of well-being and improved concentration.

We experience lighting as more pleasant and of better quality the more closely it resembles natural sunlight. Human Centric Lighting solutions realistically simulate the spectrum of sunlight over the course of the day without emitting any unwanted radiation in the UV or infrared range. This extraordinary light quality cannot be achieved with conventional lighting concepts. KITEO lighting solutions therefore rely exclusively on the award-winning PI-LED technology.

Human beings today spend the greater part of their lives indoors. Over the course of time, human civilisation has increasingly moved indoors:

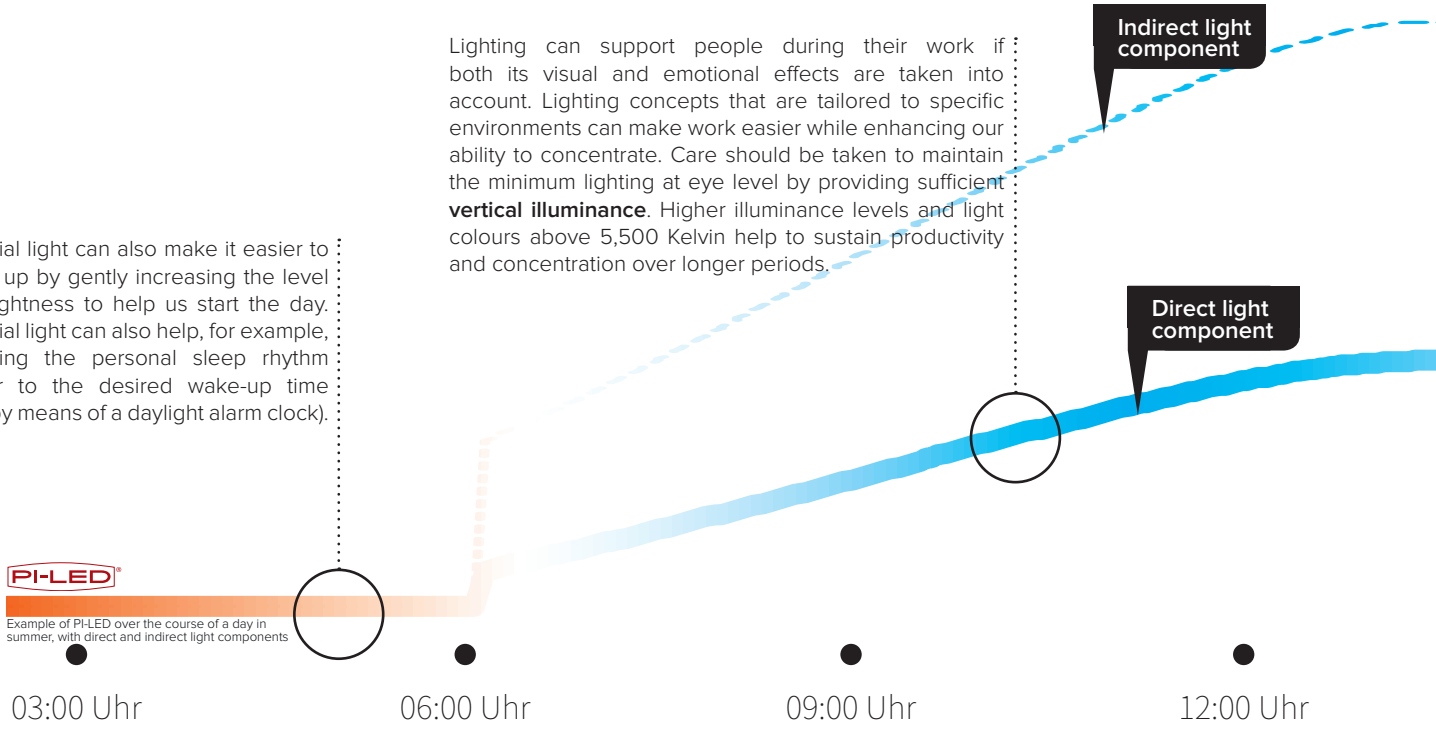


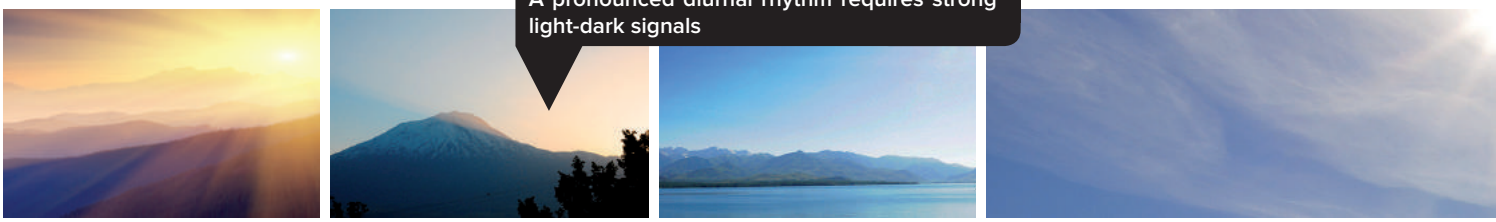
Our natural diurnal rhythm is designed to facilitate optimum sleep and relaxation during the "dark" phase, and optimum vitality and productivity during the "light" phase. During the course of evolution, this cycle has led to the development of our biorhythm – the circadian system.

HUMAN HEALTH IS DEPENDENT ON A PRONOUNCED DIURNAL RHYTHM

Lighting can support people during their work if both its visual and emotional effects are taken into account. Lighting concepts that are tailored to specific environments can make work easier while enhancing our ability to concentrate. Care should be taken to maintain the minimum lighting at eye level by providing sufficient **vertical illuminance**. Higher illuminance levels and light colours above 5,500 Kelvin help to sustain productivity and concentration over longer periods.

Artificial light can also make it easier to wake up by gently increasing the level of brightness to help us start the day. Artificial light can also help, for example, to bring the personal sleep rhythm closer to the desired wake-up time (e.g. by means of a daylight alarm clock).





In addition to the rods and cones that are responsible for human vision, our eye also contains non-visual photoreceptors that have a noticeable impact on our circadian rhythm. These receptors control our hormonal balance, especially that of melatonin, which is responsible for our wake/sleep patterns. This is exactly where the PI-LED technology comes in – supporting the human circadian rhythm by maintaining a natural balance in melatonin production.

Cool light with a high blue component activates and promotes the release of serotonin and cortisol and at the same time suppresses the release of melatonin. This significantly increases human productivity and attention.

By contrast, warm light with a high red component does not suppress the release of melatonin, which results in better relaxation and more restful sleep after an initial activation phase.

SPECTRAL DISTRIBUTION
IN COMPARISON

Colours and coloured objects are only perceived as such if the corresponding colours are present in the spectrum of the light source.

The sun's spectrum
Cloudy, at 10 a.m. in the morning

Spectrum of a
KITEO Human Centric Lighting solution
using summer day as reference

PI-LED®

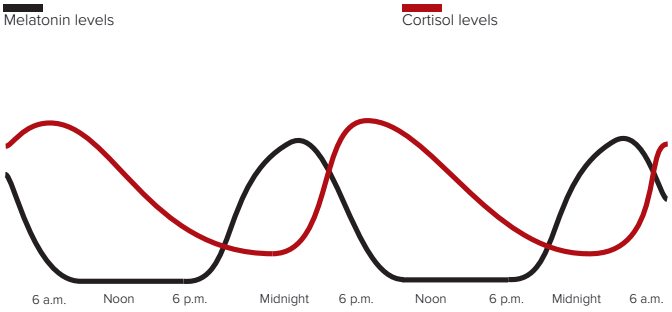
Spectrum of standard office lighting
with T5 fluorescent lamps

All images were taken with a KITEO spectroscope.

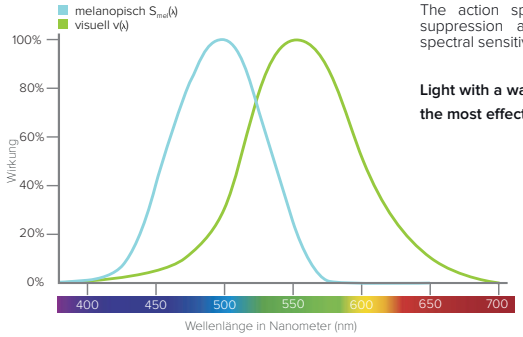
Compact fluorescent lamps have a discontinuous line spectrum, which means that certain colour components are missing. For this reason, not all colours are displayed correctly.

This causes permanent stress, as the human brain constantly tries to fill in the gaps.

THE CIRCADIAN RHYTHM

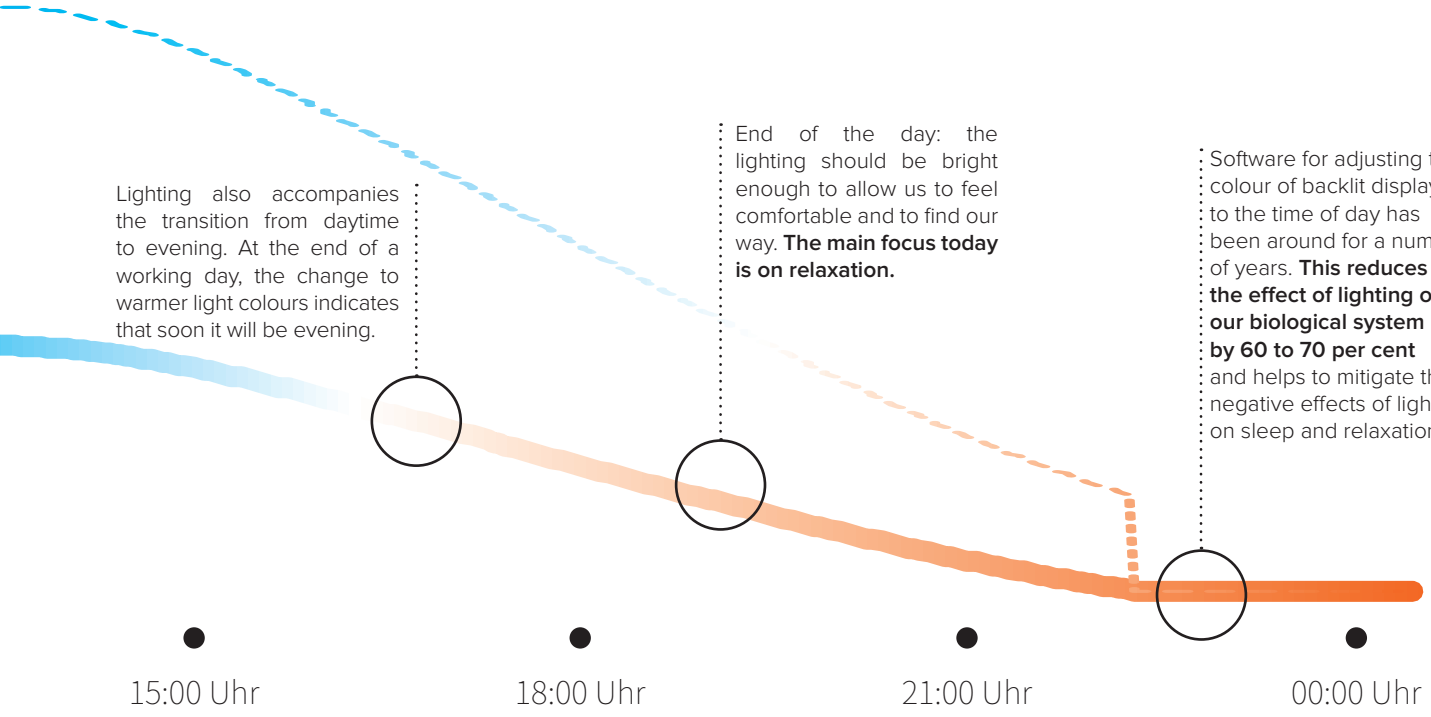


Source: "The effect of high correlated color temperature office lighting on employee wellbeing and work performance"
©2007 Mills et al; license BioMed Central Ltd. Peter R Mills, Susannah C. Tomkins and Luc JM Schlangen



The action spectrum of melatonin suppression as compared to the spectral sensitivity of the human eye:

Light with a wavelength of 480nm is the most effective biologically.



Lighting also accompanies the transition from daytime to evening. At the end of a working day, the change to warmer light colours indicates that soon it will be evening.

End of the day: the lighting should be bright enough to allow us to feel comfortable and to find our way. **The main focus today is on relaxation.**

Software for adjusting the colour of backlit displays to the time of day has been around for a number of years. **This reduces the effect of lighting on our biological system by 60 to 70 per cent** and helps to mitigate the negative effects of light on sleep and relaxation.

15:00 Uhr | 18:00 Uhr | 21:00 Uhr | 00:00 Uhr

THE EFFECTS OF LIGHT ON PEOPLE

HCL supports human health, well-being and productivity in a targeted and sustainable manner through the holistic planning and implementation of the **visual**, the **emotional** and, in particular, the **biological effects** of light.
(ZVEI definition, which is similar to the ISO CIE definition for "integrative lighting")

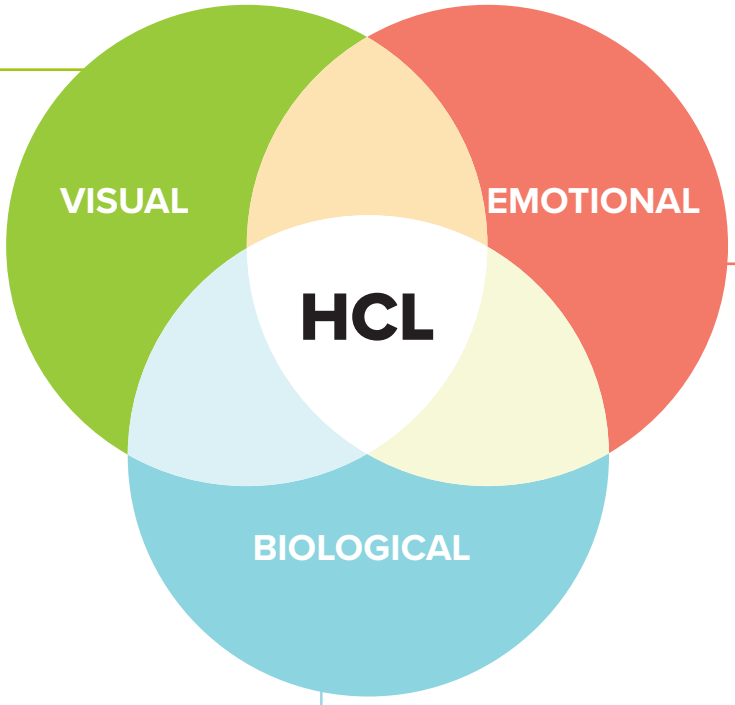
Visual effect

The aim of lighting design is always to achieve optimum visual conditions. Special requirements, such as the greater need for light on the part of the elderly, have to be incorporated and appropriately planned. The relevant standards and regulations stipulate the minimum criteria for the performance of visual tasks in working areas (e.g. EN 12464-1).

Possible criteria:

- Illuminance
- Light colours
- Colour rendering CRI>90
- Uniform illumination or accentuation
- High-contrast illumination, reflectance, luminance, etc.

IMMEDIATE EFFECT



Visual effect

Architectural, aesthetic and psychological criteria also need to be taken into account. These criteria take the form of best practices based on design rules and interdisciplinary guidelines. They are hard to quantify and cannot be found in the relevant norms and regulations.

Possible criteria:

- Light direction
- Light colours: warm and cool tones
- Fixed lighting moods, adjustable lighting moods
- The design of a room, etc.

IMMEDIATE EFFECT

Non-visual effects

These effects have a positive impact on the circadian rhythm and support daytime productivity as well as a good night's sleep. In the short term, they can increase attention and alertness levels.
The DIN SPEC 5031-100 and DIN SPEC 67600 publications, among others, contain recommendations and information on how to plan biological or melanopic effects.

Possible criteria:

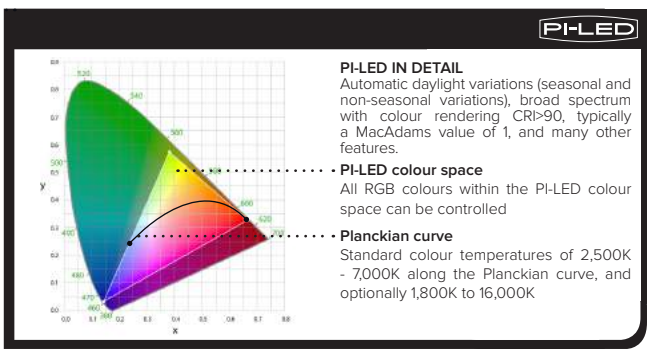
- Lighting used for activation and relaxation
- Supporting the normal human biorhythm

LASTING EFFECTS

LIGHTING CHARACTERISTICS

	Criterion / lighting characteristics*	PI-LED	WW
VISUAL	High colour rendering CRI > 90	✔	~
VISUAL	Highly efficient, up to about 140 lm / W	✔	~
VISUAL	Max. colour consistency thanks to 100% calibration	✔	~
VISUAL	CCT range of **1,800K - 16,000K** on the Planckian curve	✔	–
EMOTIONAL	Customised lighting moods and colours beyond the Planckian curve	✔ in the PI-LED triangle	–
BIOLOGICAL	Individually adjustable blue content	✔	–
BIOLOGICAL	Range of the melanopic action factor	0.2 to > 1	0.3-0.8

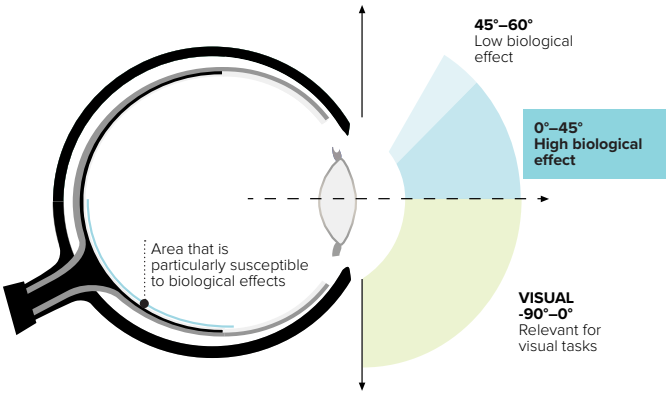
✔ yes ~possible - no



THE SENSITIVITY OF **PHOTORECEPTORS** AND **LIGHT DIRECTION**

The biological effect is primarily determined by the **vertical illuminance at eye level**. The direction from which light falls into the eye is therefore of particular importance. Indoors, the human field of vision covers the range from around 70° below to 55° above the line of vision. While our visual field is not static, it is on average directed slightly downwards, where most visual tasks are located.

When our gaze is directed at walls, for example in smaller rooms, the latter form an ideal surface that can be illuminated as a secondary light source. In larger rooms or in areas where the walls cannot be used, the ceilings provide an alternative usable surface. If bright surfaces are used, the visible luminance should not exceed the range of 500 to 1,000 cd/m^2 to avoid the risk of glare. Bright surfaces should therefore be as large as possible in order to reflect sufficient light without excessive luminance. However, it is important to avoid illuminating people directly to protect them from glare. (See Licht.de)



Apart from the visual and emotional effects, the healthy properties of PI-LED HCL largely stem from its biological effect, which is modelled on that of natural daylight.

This type of lighting thus supports the natural hormonal processes in the body at any time of day and can be tailored to people's individual preferences as well as their age.

KITEO indicates the melanopic action factor of all its PI-LED products, across the entire CCT range. This value is a light-type specific conversion factor for melanopic equivalent daylight illuminance, alpha(smel) for short.

The alpha(smel) factor describes the melanopic effect of the light source on humans and their circadian rhythm. In order to optimally support the natural human biorhythm, the release of melatonin can be minimisedby means of higher alpha(smel) values during the day and then stimulated through lower values in the evening.
PI LEDs enable the implementation of lighting that is not only visually but also biologically/melanopically effective. KITEO recommends the use of the DIN SPEC 5031-100 guidelines to ensure standard-compliant lighting designs.

MELANOPIC ACTION FACTOR

CCT [K]	VISUELLE DATEN	MELANOPISCHER WIRKFAKTOR
	Lichstrom [lm]	alpha (smel)
1.800	1650	0,226
2.000	1945	0,252
2.500	2495	0,324
2.700	2400	0,357
3.000	2300	0,407
3.500	2195	0,484
4.000	2130	0,554
4.500	2085	0,618
5.000	2055	0,676
5.500	2040	0,728
6.000	2025	0,774
6.500	2015	0,816
7.000	2010	0,852
8.000	2000	0,915
9.000	1995	0,965
10.000	1990	1,033
12.000	1970	1,168
14.000	1950	1,304
16.000	1935	1,439

Example: K-SOLIS PURE

The table below indicates the typical values for a specific PI-LED product.

Melatonin makes us tired, slows down our bodily functions and lowers activity levels, thereby facilitating a good night's sleep. It also slows down many of the body's metabolic processes and causes the body temperature to drop, thereby setting our organism to energy-saving mode, so to speak. In this phase, the body releases growth hormones that repair our cells during the night.

The melanopic action factor measures the influence of a light source on the circadian rhythm.

The melanopic value of a light source indicates the daylight equivalent of that source. This value is based on D65 daylight (CIE Standard Illuminant D65, also known as "northern daylight"), which is widely regarded as the standard. It has been calculated in such a way that the visual value of the D65 standardised daylight spectrum corresponds exactly to the melanopic value. 1,000 lux of D65 illuminance thus correspond to 1,000 lux of melanopic illuminance. The melanopsin photoreceptors in the human eye react particularly strongly to **blue light**. The range of maximum sensitivity lies at a wavelength of **480 nanometres**.

The melanopic action factor measures the circadian effect of a light source.
For the formula, see DIN SPEC 5031-100

Variations in colour temperature and daylight intensity are not the only decisive elements for synchronising our internal clock; the direction and planarity of the light hitting our eyes are equally important.
Melanopic lighting takes all these factors into account. What is most important, however, is that these elements are deployed at the right time.

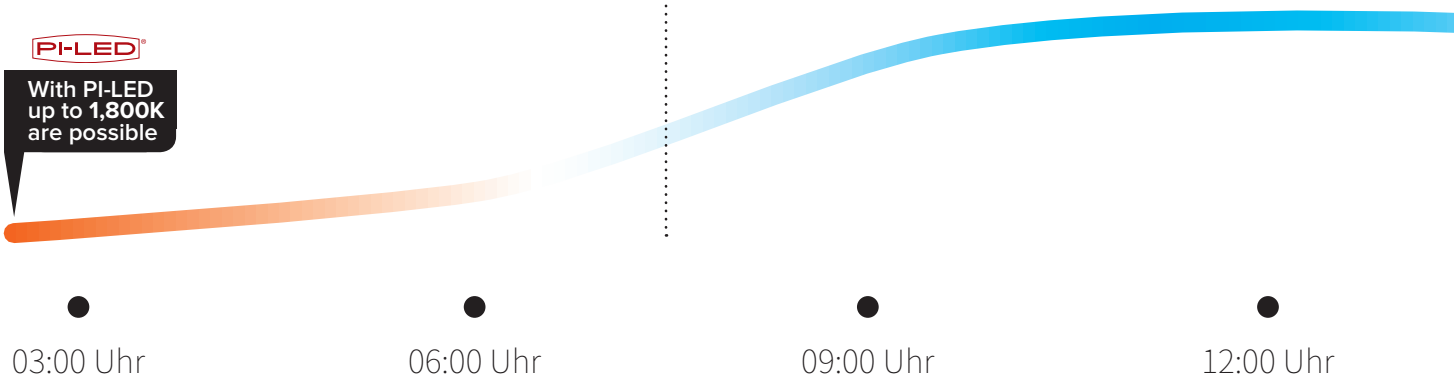
If bright surfaces are used, the visible luminance should not exceed the range of 500 to 1,000 cd/m^2 to avoid the risk of glare. Bright surfaces should therefore be as large as possible in order to reflect sufficient light without excessive luminance.

In order for artificial light to have the intended non-visual biological effect, certain minimum values of melanopic illuminance need to be met at eye level. The details of this assessment are laid down in **DIN SPEC 5031-100**. For LEDs with 6,500K the minimum value is 300lx.

At lower colour temperatures, the (photometric) minimum illuminance will be higher; e.g. 380lx at eye level in the case of an LED light source with 4,000K. On the other hand, certain maximum values should not be exceeded if the aim is to keep the melanopic effects to a minimum. In such cases, 50lx should not be exceeded, for example, if an LED with 2,700K is used.

RECOMMENDATIONS
WORKING DAY

Enhancing concentration and attention during the day
Illuminance levels of 300 to 500 lx should be maintained at eye level throughout the working day (the light quality should correspond to that of daylight). Dynamic lighting should be planned according to the natural daylight pattern on a sunny day - ideally using both direct (up to 6,500K) and indirect (up to 16,000K) components that can be controlled separately.



Individually designed lighting management systems with application-specific sensors can make a significant contribution to minimising the energy consumption of an HCL solution.

Due to the combination with daylight, using warm white lighting only during the day would create unsatisfactory lighting moods. During the day, lighting with neutral white light colours should therefore be used.

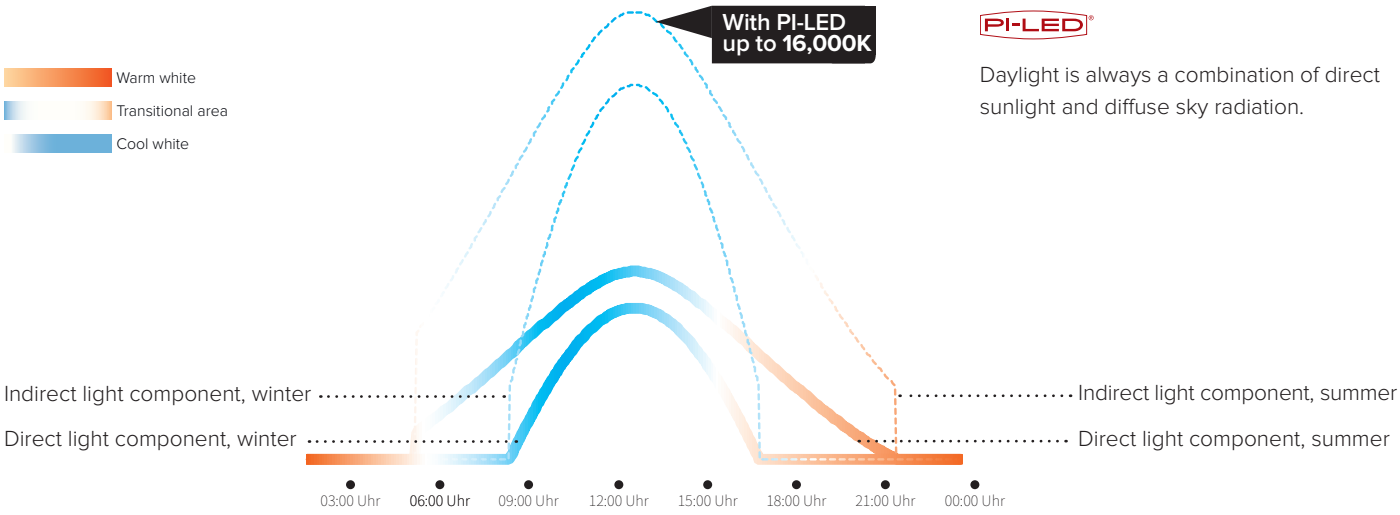
"Cool white" light with a high colour temperature but equal illuminance has a stronger effect on the biological system because it contains more melanopically active blue light compared to warm white light. The melanopic efficiency spectrum describes the relationship between the light spectrum and the biological effect (see also DIN SPEC 5031-100).

RECOMMENDATIONS
SHIFT WORK

The optimal lighting during NIGHT SHIFT WORK:
Lighting between 3,000K and 4,000K rather than daylight white should be used to support nighttime work. By controlling illuminance, it becomes possible to design dynamic lighting solutions. Cool white light should be avoided, and white light with a high red component should be used instead. This can be supported by means of dynamic lighting control.

Biologically effective light is most efficient in a range of about
-15° to +45° from the horizontal axis.

EXAMPLE OF SUMMER AND WINTER
INDIRECT AND DIRECT LIGHT COMPONENTS WITH PI-LED



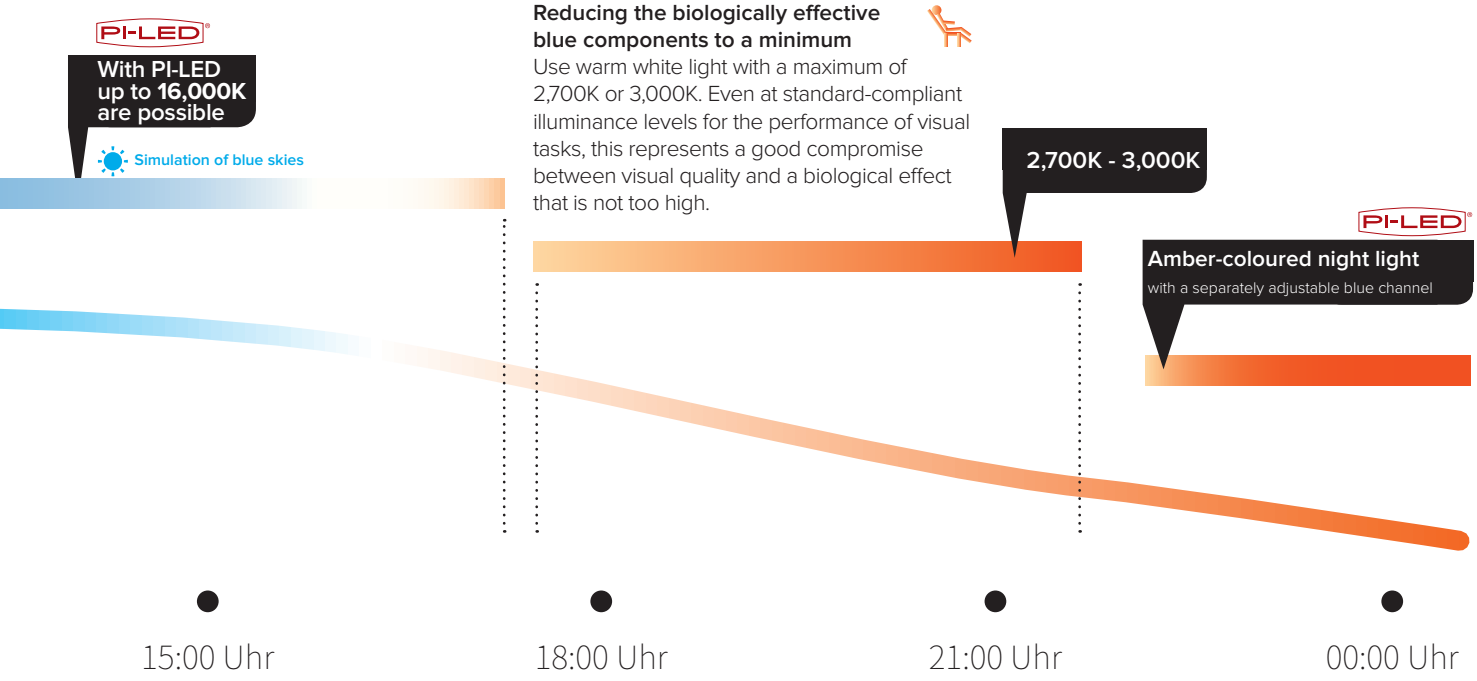
PI-LED

Daylight is always a combination of direct sunlight and diffuse sky radiation.

RECOMMENDATIONS
END OF DAY

Reducing the biologically effective blue components to a minimum

Use warm white light with a maximum of 2,700K or 3,000K. Even at standard-compliant illuminance levels for the performance of visual tasks, this represents a good compromise between visual quality and a biological effect that is not too high.



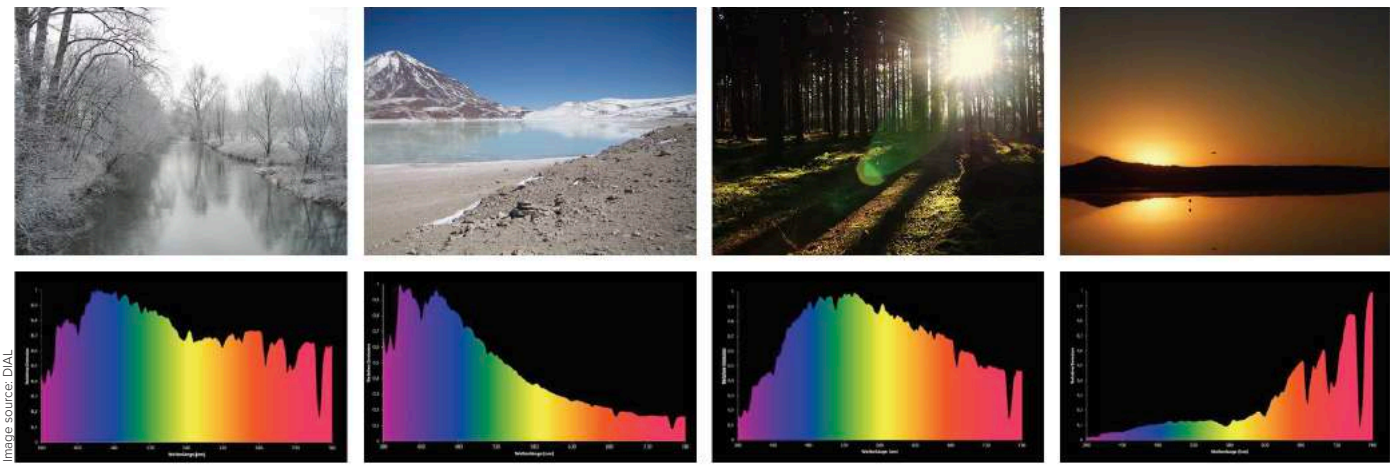


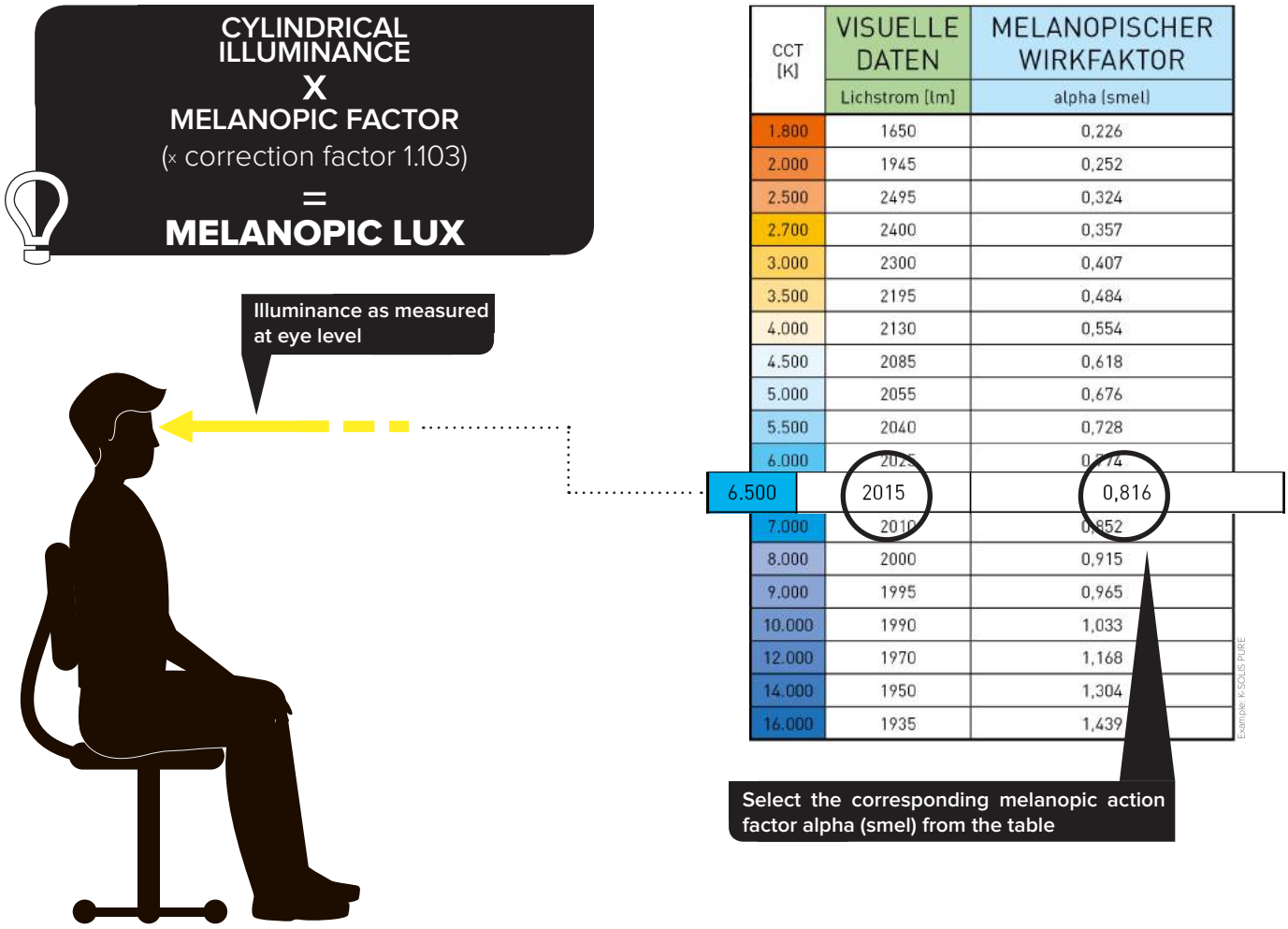
Image source: DIAL

THE HUMAN CENTRIC LIGHTING
CONCEPT

Daylight determines the factors that enable biologically effective lighting:
✓ **Illuminance**
✓ **Planarity**
✓ **Light direction**
✓ **Colour temperature** and
✓ the **dynamics of daylight variations across the day and the seasons**

MELANOPIC
LUX

An initial rough estimate can be easily drawn up at any time during the planning phase:



CCT [K]	VISUELLE DATEN	MELANOPISCHER WIRKFAKTOR
	Lichstrom [lm]	alpha (smel)
1.800	1650	0,226
2.000	1945	0,252
2.500	2495	0,324
2.700	2400	0,357
3.000	2300	0,407
3.500	2195	0,484
4.000	2130	0,554
4.500	2085	0,618
5.000	2055	0,676
5.500	2040	0,728
6.000	2025	0,774
6.500	2015	0,816
7.000	2010	0,852
8.000	2000	0,915
9.000	1995	0,965
10.000	1990	1,033
12.000	1970	1,168
14.000	1950	1,304
16.000	1935	1,439

Example: K-SOLIS PURE

For each project, two separate calculations should be carried out.

NO ACTIVATION
< 240
MELANOPIC LUX

ACTIVATION
> 240
MELANOPIC LUX

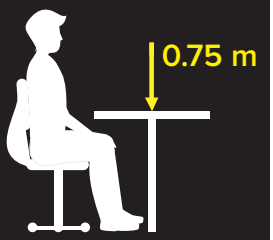
The non-visual planning component includes an **activation phase** (e.g. from 7.00 a.m. to 11.00 a.m.), during which **200 to 250lx** of melanopic equivalent daylight illuminance will hit the user's eye at a vertical angle.

During the **day**, the colour temperature in an office should be **4,000K**, for example, with a daylight equivalent based on the visual requirements.

After **sunset**, the daylight equivalent at eye level should be as close as possible to 50lx, without dropping below the visual requirements.

DIALUX & RELUX
CALCULATION OPTION

1 Insert the Eulumdat file (3,000K) and calculate the light on the vertical lighting surface (H=0.75m).

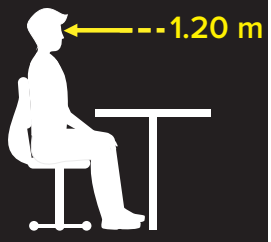


2 **Multiply**the Eulumdat file (3,000K) with the corresponding melanopic action factor from the table, then **multiply**with the correction factor 1.103 from DIN 5032-100.

3 Rewrite the file using the LDT editor and then insert the calculated values.

Re-insert the modified Eulumdat files into DiaLux.

4 Carry out a new light calculation to determine the cylindrical illuminance on the working plane (H=1.20m sitting or H=1.80m standing).



These steps need to be repeated and evaluated in the same way as for each desired light colour. (The luminous flux values from the table must be adjusted for each new light colour, given that luminaires are often measured at 3,000K, for example.)

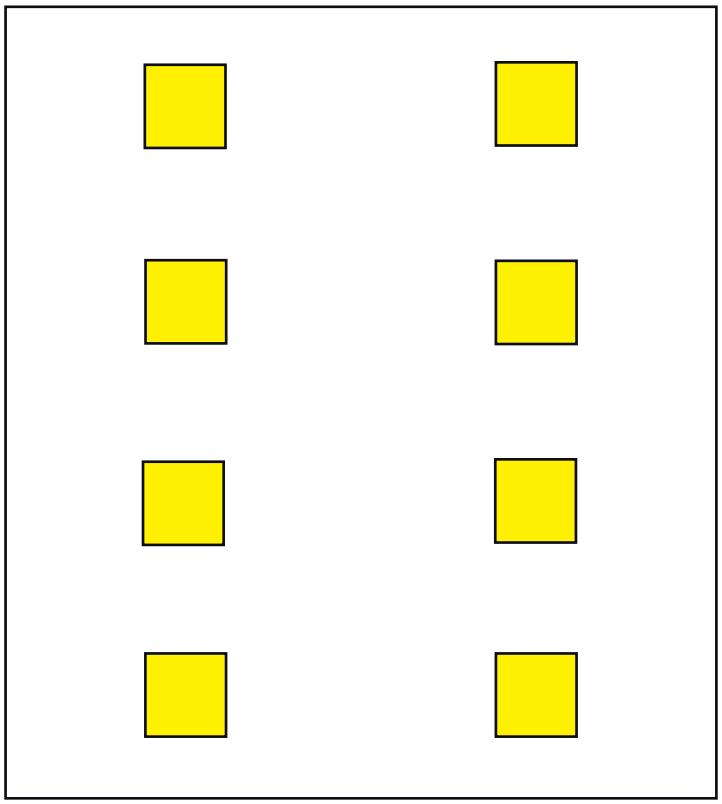
A horizontal and a cylindrical calculation need to be carried out (in both cases using the warmest light colour and the coolest light colour in the desired lighting sequence).

Only values above 240 melanopic lux are likely to have a stimulating effect.

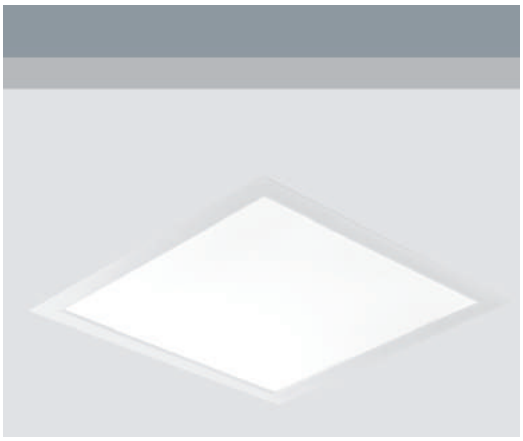
EXAMPLE
A MELANOPIC APPROACH TO OFFICE LIGHTING

Melanopic approach in a sample office with DIALux (and RELUX).

Sample office: 32.40 m^2
Ceiling height: 2.60 m

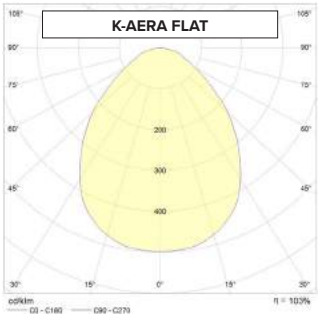


K-AERA FLAT FLOOR LIGHTING



8 units of K-AERA FLAT

Colour temperature range 1,800K - 16,000K



K-AEF-620-DA
K-Aera Flat luminaire / PI-LED / DALI DT8 / 620mm

www.kiteo.eu/k-aera-flat/

CCT [K]	VISUAL DATA	MELANOPIC ACTION FACTOR
	Luminous flux [lm]	alpha (smel)
1,800	1,775	0.258
2,000	2,010	0.297
2,500	2,630	0.386
2,700	2,890	0.419
3,000	3,300	0.467
3,500	4,000	0.540
4,000	3,960	0.606
4,500	3,880	0.665
5,000	3,820	0.718
5,500	3,780	0.766
6,000	3,750	0.808
6,500	3,725	0.846
7,000	3,710	0.879
8,000	3,690	0.937
9,000	3,675	0.985
10,000	3,665	1.024
12,000	3,660	1.083
14,000	3,655	1.127
16,000	3,655	1.160

Table: K-AERA FLAT

1 VISUAL APPROACH
EN 12464-1

Raumhöhe: 2.600 m, Montagehöhe: 2.600 m, Wartungsfaktor: 0.80 — Werte in Lux, Maßstab 1:78

Fläche	ρ [%]	E_m [lx]	E_{min} [lx]	E_{max} [lx]	g_1
Nutzebene	/	791	553	964	0.698
Boden	20	528	87	744	0.164
Decke	70	130	80	180	0.618
Wände (4)	50	302	115	647	/

Nutzebene:
Höhe: 0.850 m
Raster: 128 x 128 Punkte
Randzone: 0.500 m

Leuchten-Stückliste

Nr.	Stück	Bezeichnung (Korrekturfaktor)	Φ (Leuchte) [lm]	Φ (Lampen) [lm]	P [W]
1	8	Kiteo GmbH & Co. KG K-AEF-620-DA K-Aera Flat Leuchte4000K (1.000)	4081	3960	50.0
			Gesamt: 32646	Gesamt: 31680	400.0

Office lighting calculation at 4,000K (alternatively at 3,000K depending on the standard) to verify compliance with the standard (500lx are required for the work surface).

The calculations have to be repeated for all colour temperatures (lowest and highest) to verify compliance with the standard across all lighting moods (e.g. 2,500K and 5,500K).

2 MELANOPIC APPROACH
Calculations for 2,500K, 4,000K (3,000K) and 5,500K. The luminous flux values need to be adjusted manually in the Eulumdat file. Depending on the installation location, the calculation level should be set to either 1.20m (seated activity) or 1.80m (standing activity), since the illuminance at eye level is the decisive factor here. It should also be noted that a **cylindrical plane** needs to be created to carry out the calculation.

E_m [lx]	E_{min} [lx]	E_{max} [lx]	g_1	g_2
236	217	263	0.919	0.825

At values below 240 lux (melanopic), no stimulation takes place.

Leuchten-Stückliste

Nr.	Stück	Bezeichnung (Korrekturfaktor)	Φ (Leuchte) [lm]	Φ (Lampen) [lm]	P [W]
1	8	Kiteo GmbH & Co. KG K-AEF-620-DA MEL 4000K (1.000)	2740	2659	50.0
			Gesamt: 21921	Gesamt: ~~21272~~	400.0

Calculating the luminous flux:
Lumen * (action factor * correction factor 1.103)

At 4,000K:
3,960 lm * (0.606 * 1.103) = 2.659 lm
This new luminous flux value now has to be entered into the Eulumdat file.

3 SUMMARY / SIZING
Calculations for 2,500K, 4,000K (3,000K) and 5,500K. The number of luminaires should be adjusted as required and the calculations then need to be repeated. To generate a sufficient level of stimulation, the luminaire will probably have to be oversized (larger than what the standard requires).

	VISUAL		MELANOPIC		MELATONIN
Colour temperature [K]	Luminous flux [lm]	Illuminance [lx] at the level of use	Luminous flux [lm]	Illuminance[lx] at eye level	Activation No activation
2,500	2,630	525	1,120	102	NO ACTIVATION
3,000	3,300	659	1,700	152	NO ACTIVATION
4,000	3,960	791	2,659	236	NO ACTIVATION
5,500	3,780	755	3,195	284	ACTIVATION

In the example shown, activation only takes place at a colour temperature of 5,500K; standard office lighting at 4,000K does not suppress the melatonin release and hence has no stimulating effect.

At values below 240 lux (melanopic), there is no melatonin suppression and hence no stimulation.

UNLIMITED
LIGHTING POTENTIAL

By now, various scientific studies have proven that melanopic lighting reduces the error rate of students while also contributing significantly to mental regeneration. And the positive effects are also clearly evident at workplaces. In many cases, increases in employee productivity and motivation went hand in hand.

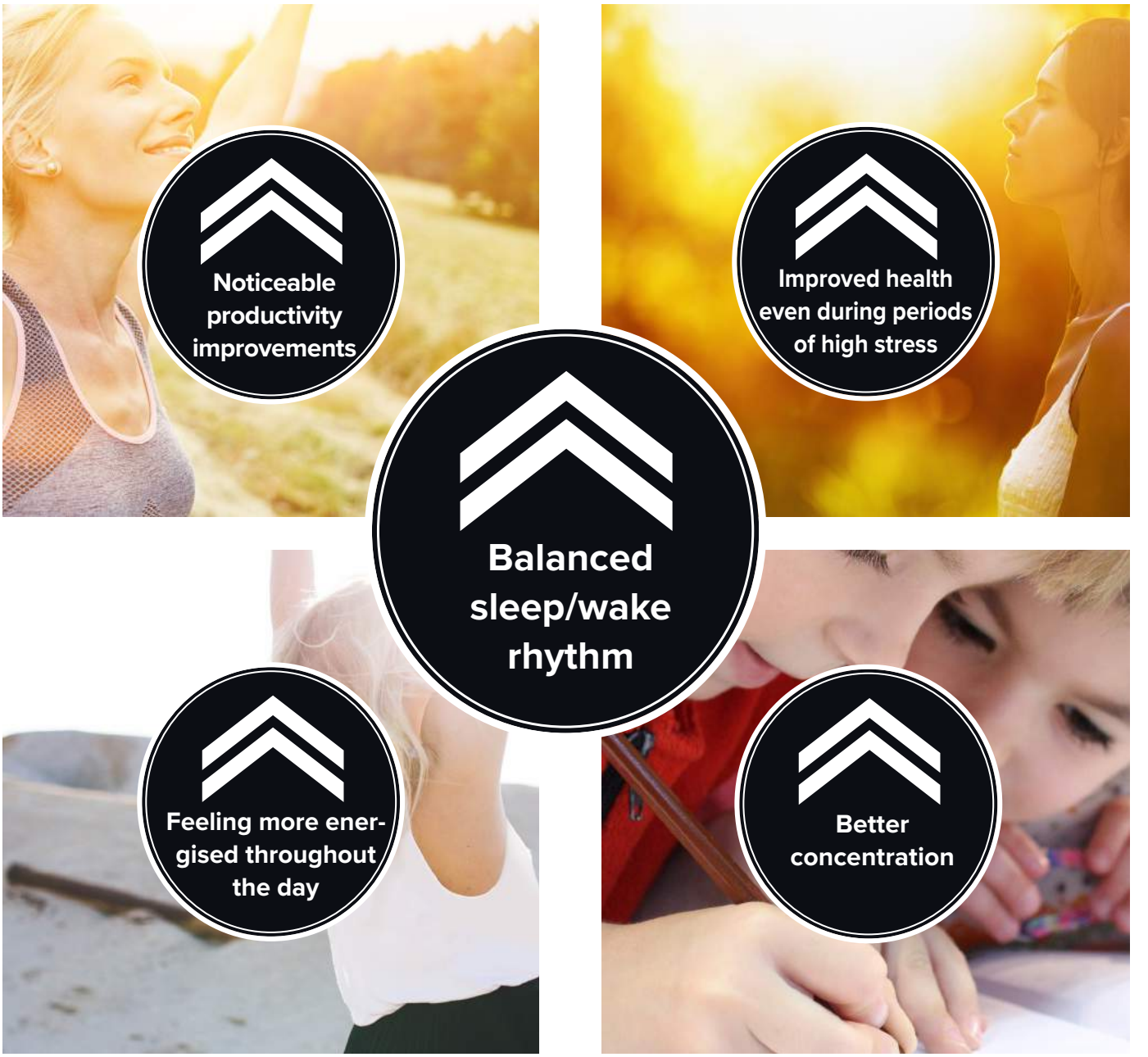
Thanks to the comprehensive range of options, PI-LED can be used across all common luminaire types and applications.
Regardless of project size and type, melanopic lighting always has a positive impact on concentration and productivity, while also improving sleep patterns through the use of biorhythmic light.

Source: "The effect of high correlated color temperature office lighting on employee wellbeing and work performance" © Mills et al; licensee BioMed Central Ltd. Peter R Mills, Susannah C. Tomkins and Luc JM Schlangen

Recommended luminaire types for PI-LED systems:

Lighting panels | Spots | Linear lighting | Decorative lighting | Floor lamps

The 2018 Market Research Report on "Global HCL and Environmental Lighting" ranked LUMITECH first among the top key vendors globally.



EDUCATION

BENEFITS
FOR CHILDREN AND ADOLESCENTS

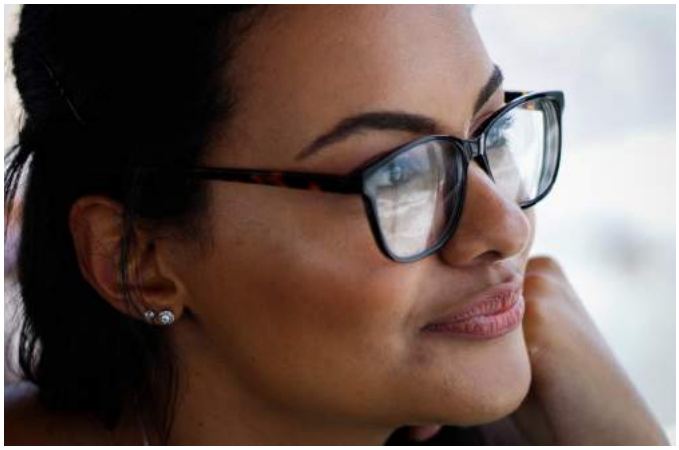
- **Improved concentration**
- **Reduced hyperactivity**
- **Lower rates of fatigue**
- **Balanced circadian rhythm**
- **Feeling more energetic**
- **Noticeable increase in motivation**

Numerous studies have shown that Human Centric Lighting can significantly improve student performance and well-being.

In a study conducted by the University Hospital Hamburg-Eppendorf between October 2007 and June 2008, reading performance increased by 35%, while the students' error rate decreased by 45%. Movement disorders meanwhile were down by 76%. At the end of the study, which included 116 pupils and 11 teachers, the test subjects wanted to retain the "new" lighting situation.

Source: "Die Wirksamkeit von dynamischen Licht im Schulunterricht" (The effectiveness of dynamic lighting in classroom settings), University Hospital Hamburg-Eppendorf, Nino Wessolowski

OFFICES



BENEFITS
FOR COMPANIES, EMPLOYEES AND WORKERS

- **High employee satisfaction**
  - ✓ Increased productivity*
  - ✓ Lower employee turnover*
  - ✓ Fewer sick days*
- **Increased productivity**
  - ✓ Improved performance*
  - ✓ Activation, relaxation and reduction of stress levels*

***Costs savings as a result**

HEALTHCARE

BENEFITS
FOR PATIENTS

- **Improved sleep/wake rhythm**
  - ✓ Supporting the recovery process
  - ✓ Potentially lower drug dosages
- **Reduced stress levels prior to surgery**
  - ✓ Calming effect thanks to amber lighting
- **Positive mental stimulation**
- **Patients with dementia: reactivation of the inner clock thanks to Human Centric Lighting**

BENEFITS
FOR STAFF

- **Improved work performance, concentration and energy**
  - ✓ In emergencies: better concentration thanks to cool white lighting
- **Improved sleep/wake rhythm**
  - ✓ Improved health
  - ✓ Greater activation during the day
  - ✓ Lower risk of accidents at night
  - ✓ Fewer sick days
- **High visibility of injuries (during rounds) and hygiene-related issues (blood, dust)**

BENEFITS
DURING SURGERY

- **Improved visibility of anatomical details**
- **Stimulated metabolism and lower stress levels during endoscopic surgery**
  - ✓ Situation-specific colour temperatures to enhance the contrast ratio of monitors (e.g.: orange and red when inserting a cannula for better visibility of the blood vessels)
- **Sensory stimulation**
  - ✓ Stimulating patients' senses by using special colours in recovery rooms

RETAIL

BENEFITS
FOR CUSTOMERS AND RETAILERS

- **Turning supermarket shopping into an event (a positive shopping experience)**
- **The product colours can be faithfully rendered in accordance with the natural daylight conditions**
- **Prompting customers to buy & to stay for longer**
- **Increased customer satisfaction**
- **Reducing the number of returned products**

How customers perceive a retail space and the way it makes them feel has a significant impact on purchasing behaviour. To be optimally effective, retail lighting needs to simulate daylight conditions, by presenting the colour, material and feel of the product in the right light.

The sense of well-being that customers and staff experience also has an impact on sales. Human Centric Lighting can significantly improve the health and well-being of customers and employees. This can be best implemented across open spaces and in the checkout area. PI-LED can also be optimally used for scenic effect, for example by using the company's corporate colours to attract attention at night.

ART

BENEFITS
FOR MUSEUMS AND GALLERIES

- **Advantages for conservation**
  - ✓ Illumination without any harmful spectral components (in the UV and IR range)
- **Artist-oriented lighting**
  - ✓ Reproducing the lighting conditions that the artist had in mind while creating the work candlelight, daylight, etc.)
- **Can be individually adjusted to each work of art**
  - ✓ Light as a means to support the staging of artworks and performances

Our notion of "ideal" light is highly subjective, which makes it very difficult to define. However, there are many different approaches for determining the right type of lighting.

Each work of art is created under different lighting conditions, for example changing colour temperatures due to the presence of daylight, candlelight or artificial light. In other words, it could be argued that the history of art is also one of "dynamic lighting".

And today, dynamic lighting is becoming ever more important worldwide. Today's lighting systems need to be able to adapt to changing circumstances, such as the diversity of materials and forms used in art.

"Everything can be changed, deformed or eliminated by the light. It is just as supple as the brush."

– Man Ray

SHOWROOMS

BENEFITS
FOR EXHIBITORS AND CUSTOMERS

MOODS:

- ✓ Exhibition: clear visibility of the exhibited products (light colour, high CRI)
- ✓ Setting the stage: achieving additional "wow" effects
- ✓ Events: dynamic lighting with white tones and colours

+ The showroom changes

+ Increased customer attention

+ Lighting for evening events

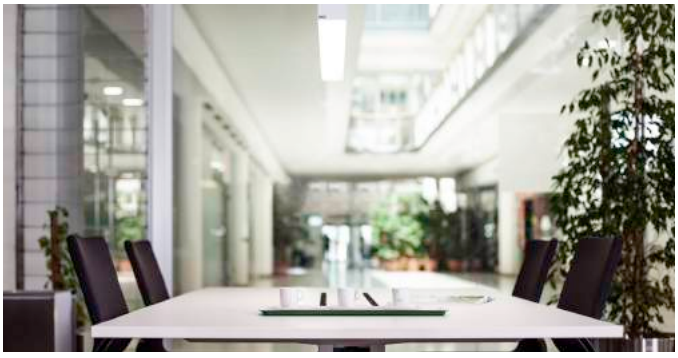
SEMINAR ROOMS & MEETING ROOMS

BENEFITS
FOR COMPANIES AND PARTICIPANTS

MOODS:

- ✓ Traditional presentations
- ✓ Meetings
- ✓ Tasks that require concentration
- ✓ Creative work
- ✓ Different moods for morning / noon / evening

+ Lighting moods that support users during meetings



HOTELS & CATERING

BENEFITS
FOR OPERATORS AND VISITORS

LOBBIES & RESTAURANTS:
Dynamic moods

- ✓ In the morning: fresh white tones (warm/cool) = activation
- ✓ At noon: cool white tones
- ✓ In the evening: warm white tones up to 1,800K are possible = relaxation

WELLNESS:
In addition to moods for the different times of day, various colour moods are also available

SOPHISTICATED LIVING

BENEFITS
FOR RESIDENTS

MOODS:
dynamic

- ✓ In the morning: fresh white tones (warm/cool) = activation
- ✓ At noon: cool white tones
- ✓ In the evening: warm white tones up to 1,800K are possible = relaxation

- ✚ **Creating feel-good spaces**
- ✚ **Nighttime mood:**
  Reducing the blue components makes it possible to fall asleep right away.

REFERENCES

EDUCATION

Munich University of Applied Sciences
The classroom of the future | Munich, Germany
School | **Kongsgårdmoen skole** | Kongsgardsmoen, Norway

OFFICES

Office | **Büro Bauer** | Vienna, Austria

Trading room | **RBI** | Vienna, Austria

Public buildings | **Municipal offices** | St Martin, Austria

Office | **Sprenger Autobahnhof AG** | Zurich Airport, Switzerland

Büro | **Omicron Electronics** | Klaus, Austria

HEALTHCARE

Hospital | **KH Hietzing** | Vienna, Austria

Rehabilitation centre | **Weißer Hof** | Klosterneuburg, Austria

Hospital | **KH Bruck an der Mur** | Austria

Study | **Floor lamp "Skylight"** | Lucerne University of Applied Sciences, Switzerland

Radiology centre | **Spitalzentrum Biel** | Biel, Switzerland

RETAIL

Shop | **Heimatgold** | Kitzbühel, Austria

Shop | **Victor Steinwender** | Vienna, Austria

Butcher shop | **Müller** | Baden AG, Switzerland

ART

Museum | **Arnulf Rainer Museum** | Baden, Austria

Museum | **Landesmuseum Eisenstadt** | Eisenstadt, Austria

Studio Occular art project | **White Cube** | Vienna, Austria

SHOWROOMS

Showroom | **Richter + Frenzel** | Munich, Germany

Showroom | **Neudörfler** | Vienna, Austria

Showroom | **Vitus König** | Aalen, Germany

MEETING ROOMS

Hotel | **Pannonia Tower** | Parndorf, Austria

Bank | **Raiffeisen Private Banking** | Deutschlandsberg, Austria

Office | **Omicron** | Vienna, Austria

Meeting rooms | **Swiss public television** | Zurich, Switzerland

HOTELS & CATERING

Hotel | **Lambrechterhof** | St Lambrecht, Austria

Hotel | **Hilton** | Vienna, Austria

Thermal baths | **Familientherme Stegersbach** | Stegersbach, Austria

RESIDENTIAL

Private residence | **Schön family residence**

Penthouse | **Regis** | Vienna, Austria

CHECKLIST

CHECKLIST FOR THE PLANNING OF DYNAMIC LIGHTING SOLUTIONS
A HELPFUL TOOL FOR LIGHTING DESIGNERS

☐ GENERAL INFORMATION

PROJECT:

.....

CUSTOMER:

.....

.....

General lighting requirements:

.....

.....

What is the main purpose of lighting?

.....

.....

What added value should lighting design provide?

.....

.....

.....

Does the illumination serve representative as well as functional purposes?
(design, image, marketing)

.....

.....

APPLICATIONS:

Room type	Dynamic lighting	Activity					Needs				
		Early morning	Late morning	Noon	Afternoon	Evening	Early morning	Late morning	Noon	Afternoon	Evening
Seminar room	☑	*Meeting*	*Creative workshop*	*Lunch, discussion*	*Concentra-ted work*	*Event*	*3,000 - 4,500 K*	*4,000 - 5,500 K*	*Daylight*	*Daylight*	*Colour moods*
	☐										
	☐										
	☐										
	☐										
	☐										

CONTROL SYSTEM:

☐ DALI ☐ KNX ☐ NEOLINK/ZIGBEE ☐ DARA ☐ CASAMBI ☐ .....

☐ FULLY AUTOMATIC (without user access) ☐ AVAILABLE SCENES (see below)

Room type	Moods	Control system
Seminar room	*Meeting, creative work, lunch, concentrated Work, presentation (projector)*	*Touch panel, app (smartphone / tablet)*

☐ VISUAL

IMPORTANT CONSIDERATIONS FOR GOOD QUALITY LIGHTING

- ☐ Lighting environment
- ☐ Luminance
- ☐ Reflectance
- ☐ Illuminance levels
- ☐ Type of visual task
- ☐ Glare
- ☐ Cylindrical illuminance
  (important for the calculation of melanopic illuminance)
- ☐ Light colours
- ☐ Colour rendering
- ☐ Flicker-free
- ☐ Maintenance considerations
- ☐ Efficiency requirements
- ☐ Variability of light
- ☐ .....

☐ EMOTIONAL

It is no secret that well-designed lighting has a positive impact. Lighting design is not only about the aesthetic appearance of the luminaires themselves, but about the overall effect in terms of how spaces, surfaces and objects are illuminated. In other words, it's about creating a mood.

- ☐ The interplay of the materials and light colours used (warm, cool, colours)
- ☐ Light direction (wallwasher, wall illumination, flat, spot-like, linear)
- ☐ Technical requirements (compliance with the applicable standards)
- ☐ Creative (stylish, playful or artistic) lighting, creative spaces, feel-good lighting, interactive areas, etc.
- ☐ .....

☐ BIOLOGICAL

Long-term biological effects on humans
Improving concentration and attention during the day

- ☐ Classic daylight simulation
- ☐ Maintaining illuminance levels of 300 to 500 lx at eye level throughout the working day
- ☐ The level of lighting should correspond to the quality of daylight
- ☐ Using cool colour temperatures until the early afternoon
- ☐ Planning for dynamic illuminance levels throughout the day (creative spaces, feel-good lighting, interactive areas, etc.)
- ☐ Planning for dynamic colour temperatures throughout the day (e.g. similar to daylight)
- ☐ Reducing the blue light component to a minimum in the evening and at night, using warm white light (max. 3,000K to 4,000K, depending on the activity)
- ☐ Maintaining the necessary illuminance levels for visual tasks

☐ NOTES

.....

.....

CONTACT INFORMATION

Contact an expert for assistance and recommendations:

YOUR LIGHTING DESIGNER

YOUR LIGHTING CONSULTANT

Additional information on how to design dynamic lighting systems can be found in "licht-wissen 21 - Guide to Human Centric Lighting (HCL)", published by Licht.de

PLANNING
STANDARDS AND GUIDELINES

CIE DIS 026 / E: 2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light

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

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

DIN 5035-7 Artificial Lighting – Part 7: Lighting of interiors with visual displays work stations

EN 12665 Light and Lighting – Basic terms and criteria for specifying lighting requirements

DIN V 18599 Energy efficiency of buildings – Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting

DIN EN 15193 Energy performance of buildings – Energy requirements for lighting

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

DIN SPEC 67600 Biologically effective illumination – Design guidelines

ASR A3.4 Technical rules for workplace lighting

This planning aid
is primarily based on the following
Licht.de publications:

No. 19, "Impact of Light on Human Beings"
No. 21, "Guide to Human Centric Lighting (HCL)"

These publication are available for download at www.licht.de

LINKS
WEBSITES

www.licht.de

http://lightingforpeople.eu/

PUBLICATIONS
SELECTED READINGS

KAN Kommission Arbeitsschutz und Normung, Gesicherte arbeitsschutzrelevante Erkenntnisse über die nichtvisuelle Wirkung von Licht auf den Menschen. Eine Literaturstudie, 2017.

LiTG Deutsche Lichttechnische Gesellschaft e.V., Leistungsbilder Lichtplanung – Teil 1 »Tages- und Kunstlicht« Praxisleitfaden für die Arbeitsschritte im Rahmen moderner Lichtplanung, 2019.

The »Weimar Theses« for lighting designers, engineers and architects. »INTEGRATIVE LIGHTING QUALITY« for an all oriented, attractive lighting design, 2017.

DGUV Deutsche Gesetzliche Unfallversicherung, DGUV Information 215-220, 2018.

Barkmann, C., N. Wessolowski, et al., Applicability and efficacy of variable light in schools. Physiology & Behavior, 2011.

Berson, D.M., F.A. Dunn and M. Takao, Phototransduction by retinal ganglion cells that set the circadian clock. Science, 2002.

Brainard, G.C., et al., Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. J Neurosci, 2001.

Cajochen, C., Alerting effects of light. Sleep Med Rev, 2007.

Cajochen, C., R.D. Biase and M. Imai, Interhemispheric EEG asymmetries during unilateral bright-light exposure and subsequent sleep in humans. Am J Physiol Regul Integr Comp Physiol, 2008.

Cajochen, C., et al., Evening exposure to blue light stimulates the expression of the clock gene PER2 in humans. Eur J Neurosci, 2006.

Cajochen, C., et al., High sensitivity of human melatonin, alertness, thermoregulation, and heart rate to short wavelength light. J Clin Endocrinol Metab, 2005.

Figueiro, M.G., M.S. Rea and J.D. Bullough, Circadian effectiveness of two polychromatic lights in suppressing human nocturnal melatonin. Neurosci Lett, 2006.

Gall, D., Die Messung circadianer Strahlungsgrößen, Tagungsband Licht und Gesundheit, 2004: Berlin.

Gall, D. and Bieske, K., Definition and measurement of circadian radiometric quantities, in CIE Symposium ,04: Light and Health: non-visual effects. 2004.

Glickman, G., et al., Inferior retinal light exposure is more effective than superior retinal exposure in suppressing melatonin in humans. J Biol Rhythms, 2003.

Glickman, G., et al., Light therapy for seasonal affective disorder with blue narrow- band light-emitting diodes (LEDs). Biol Psychiatry, 2006.

Hanifin, J.P. and G.C. Brainard, Photoreception for circadian, neuroendocrine, and neurobehavioral regulation. J Physiol Anthropol, 2007.

Juslén, Henri und Fassian, Matthias, Beleuchtung, Produktivität und Wohlbefinden – wissenschaftiche Studien in industrieller Umgebung, Tagungsband zur LICHT 2004 Dortmund (Langfassung auf der CD-Rom unter „Licht und Gesundheit"). Leproult, R., et al., Transition from dim to bright light in the morning induces an immediate elevation of cortisol levels. J Clin Endocrinol Metab, 2001.

Lockley, S.W., G.C. Brainard and C.A. Czeisler, High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light. J Clin Endocrinol Metab, 2003.

Lockley, S.W., et al., Short-wavelength sensitivity for the direct effects of light on alertness, vigilance, and the waking electroencephalogram in humans. Sleep, 2006.

Lucas, R. J., S. N. Peirson, et al., Measuring and using light in the melanopsin age. Trends Neurosci, 2014.

Mills, P.R., S.C. Tomkins and L.J. Schlangen, The effect of high correlated colour temperature office lighting on employee wellbeing and work performance. J Circadian Rhythms, 2007.

Mollenkopf, H. und Heeg S., Gute Praxis: Hüfingen – Therapeutisch wirksames Licht im Pflegeheim. DeSS orientiert, 2010.

Panda, S., et al., Melanopsin (Opn4) requirement for normal light-induced circadian phase shifting. Science, 2002.

Panda, S., et al., Illumination of the melanopsin signaling pathway. Science, 2005.

Piazena, H., Steuerung der Melatoninsuppression durch Licht – Grundlagen, Charakterisierung und Risikobewertung, in 2. DIN Expertenforum Wirkung des Lichts auf den Menschen, DIN, Editor. 2008

Pulivarthy, S.R., et al., Reciprocity between phase shifts and amplitude changes in the mammalian circadian clock. Proc Natl Acad Sci U S A, 2007.

Riemersma-van der Lek, R.F., et al., Effect of bright light and melatonin on cognitive and noncognitive function in elderly residents of group care facilities: a randomized controlled trial. JAMA, 2008.

Ruger, M., et al., Nasal versus temporal illumination of the human retina: effects on core body temperature, melatonin, and circadian phase. J Biol Rhythms, 2005.

Staedt, J., Kann Licht die Liegedauer in der Psychiatrie beeinflussen, in 2. DIN Expertenforum Wirkung des Lichts auf den Menschen, DIN, Editor. 2008

Staedt, J., et al., Einfluss erhöhter Lichtintensität auf die Verweildauer von stationär behandelten depressiven Patienten. Nervenheilkunde, 2009.

Takasu, N.N., et al., Repeated exposures to daytime bright light increase nocturnal melatonin rise and maintain circadian phase in young subjects under fixed sleep schedule. Am J Physiol Regul Integr Comp Physiol, 2006.

Thapan, K., J. Arendt and D.J. Skene, An action spectrum for melatonin suppression: evidence for a novel non-rod, noncone photoreceptor system in humans. J Physiol, 2001.

Vandewalle, G., et al., Wavelength-dependent modulation of brain responses to a working memory task by daytime light exposure. Cereb Cortex, 2007.

Vandewalle, G., et al., Brain responses to violet, blue, and green monochromatic light exposures in humans: prominent role of blue light and the brainstem. PLoS ONE, 2007.

Van Someren, E.J., A randomized clinical trial on the effect of long-term whole-day bright light exposure in elderly residents, in 2. DIN Expertenforum Wirkung des Lichts auf den Menschen, 2008.

Vetter, C., M. Juda, et al., Blue-enriched office light competes with natural light as a zeitgeber. Scand J Work Environ Health, 2011.
Wirz-Justice, A. and J. Staedt, Lichttherapie nicht nur bei Winterdepression. Schweiz Zeitschr Psychiatrie Neurol, 2008.

NOTES

NOTES

KITEO GmbH & Co. KG
Landsberger Str. 310
80687 Munich
www.kiteo.eu

LUMITECH Produktion- und Entwicklung GmbH
Technologiepark 10
8380 Jennersdorf
www.lumitech.com

LUMITECH Schweiz GmbH
Baslerstrasse 30
8048 Zurich
www.lumitech.com

Melanopic lighting design 2019
We reserve the right to make technical changes and to correct errors and misprints.
Art. No.: LP-2019-DE-V2

www.kiteo.eu
www.lumitech.com