BUREAU OF INDIAN STANDARDS
DRAFT FOR COMMENTS ONLY

Draft National Lighting Code of India

Part 11 Human Centric Lighting

First Revision of SP 72 (Part 11)

Illumination Engineering and Luminaries Sectional Committee, ETD 49

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FOREWORD

(Formal clauses of the draft will be added later)

Light has a greater significance beyond its ability to facilitate vision and spatial perception, in addition to enabling vision, retinal photoreceptors also has a pathway to diverse brain locations (supra chiasmatic nucleus) which triggers biological effects that significantly regulate human health, performance and well-being especially mood and sleep patterns. The conventional electric light sources are being replaced by digital LED technology at a rapid pace, which necessitates lighting professionals to incorporate new quality features into their designs, apart from managing physical variables like contrast and glare. The understanding of the biological impact of lighting, necessitates integrated and holistic Human Centric Lighting (HCL) approach optimizing the visual, biological and emotional impact of light on individuals.

Draft National Lighting Code of India

PART 11 HUMAN CENTRIC LIGHTING

(First Revision)

1 SCOPE

This Part of the code (Part 11) covers the impact of lighting on biological, psychological effects of human centric lighting. it also includes approach, design, operation, applications of integrated lighting which is more human centric lighting**.**

2 NORMATIVE REFRENCES

This part and section of the code is based on the following Standards:

IS / Others Standards	***Title***
IS 3646 (Part 1):1992 *(Under Revision)*	Code of practice for interior illumination: Part 1 general requirements and recommendations for working interiors (First Revision)
EN 12464-1: 2021	Light and lighting - Lighting of work places - Part 1: Indoor work places
CIE Position Statement on Integrative Lighting RECOMMENDING PROPER LIGHT AT THE PROPER TIME 3rd EDITION 1August 30, 2024	

3 TERMINALOGY

3.1 Body Clock

Body clock is the internal biological mechanism which causes the body to automatically behave in particular ways at particular times of the day.

.3.2 Circadian Rhythm

Circadian rhythm is the 24hour internal clock in the brain that regulates cycles of alertness and sleepiness by responding to light changes in our environment.

3.3 Human Centric Lighting

Common Term used in the lighting industry that enhances human experience, performance, health or wellbeing

3.4 Integrative Lighting

As the official term for lighting that is specifically intended to integrate visual and nonvisual effects, producing physiological and psychological effects on humans that are reflected in scientific evidence. (CIE 2020a, term17-29-028)

3.5 Melanopic EDI

Melanopic EDI is an international standard metric for the impact of light on melanopsin, the photoreceptors that mediate the nonvisual effects of light, including the acute alerting effects, melatonin suppression, and circadian phase shifting. Its unit is lux.

3.6 Spectral Sensitivity

Spectral sensitivity is the relative efficiency of detection, of light or other signal, as a function of the frequency or wavelength of the signal.

3.7 Tunable Lighting

Tunable white lighting technology is defined as the ability to control a light source's color temperature output.

4 BENEFITS OF INTEGRATED HUMAN CENTRIC LIGHTING (HCL)

4.1 Importance to Health

The circadian system, often referred to as the "body clock," is responsible for regulating various biological functions in our body, including sleep, hunger, body temperature, blood pressure, and the release of sleep and stress hormones like melatonin and cortisol. When the circadian rhythm is well-coordinated, it optimizes the body's alertness, mood, and sleep cycle, leading to improved sleep quality and better recovery. However, if there is a lack of synchronization or disruption to the circadian rhythm, it can result in decreased physiological functions, neurobehavioral performance, and sleep quality.

4.2 Human Body Clock

Light has an impact on the functioning of a human body. Three types of lighting needs have been identified that influences the people’s wellbeing.

4.2.1 *Visual Need*

Needs which are to be appropriately fulfilled in order to perform the visual tasks.

4.2.2 *Emotional Lighting Need*

Emotional light includes the right ambiance for a specific space, such as residential, retail, hospitality, office and road applications.

4.2.3 *Biological Lighting Need*

This is extremely crucial for the people’s wellbeing. Though everyone has been affected by this biological need since humanity is created, however it is studied and discovered very recently.

Recent research has revealed that light affects not only the rods and cones, but also a third receptor, which has been identified as the missing link in our understanding of how light impacts our health and wellbeing. This third receptor influences various hormones in the brain, including melatonin, which is produced in low light conditions or darkness, and cortisol, a stress hormone produced in higher light conditions. Medical scientists have discovered that approximately 1% of the ganglion cells in our retina, known as intrinsic photosensitive Retinal Ganglion Cells (ipRGCs), are sensitive to light. These cells are directly connected to the biological clock in the brain, which in turn regulates the release of certain hormones in body, including melatonin and cortisol. When light falls on the surface of these cells, it creates complex reactions and generates electrical impulses that are sent to the Suprachiasmatic Nuclei (SCN) biological clock. This clock is responsible for regulating our circadian (daily) and circannual (seasonal) rhythms. Continuous studies and investigation in all manner of neuro-bio-behavioural effects of light indicates evidence of interconnections between the photoreceptors, and not a strict division between functions.

4.3 Circadian Rhythm

The Earth's rotation around its axis takes precisely 24 hours, creating a 24-hour cycle of light and darkness. This cycle regulates various bodily processes, including the sleep-wake cycle, body temperature, heart rate, and the timing of hormone production. The Suprachiasmatic Nuclei (SCN) plays a significant role in regulating the sleep cycle and the production of cortisol, known as the stress or energy hormone, and melatonin, the sleep hormone. These hormones play a crucial role in controlling the body's alertness and sleep. Below Fig. 1 and Fig. 2 elaborates the typical rhythm of body temperature along with the variations of cortisol and melatonin during the cycle

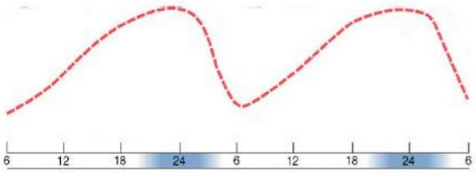


Fig.1 Double Plot (2x24 hours) of Typical Daily Rhythms of Body Temperature Relative Scale)

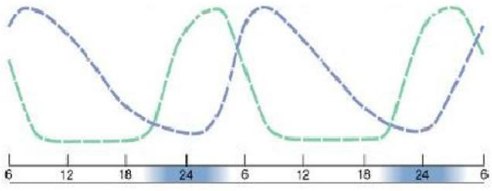


Fig 2 Double Plot (2X24 Hours) of Typical Daily Rhythms of Cortisol (Blue) and Melatonin Green

In the morning, with the rise of the Sun, the body's cortisol (stress hormone) levels increase, preparing the body for the day's activities. Simultaneously, the sleep hormone melatonin levels drop, contributing to improved activity levels and alertness throughout the day. This natural hormonal shift influences the body's sleep-wake cycle.

Melatonin is responsible for inducing feelings of sleepiness and relaxation, while cortisol promotes wakefulness and activity. Consequently, humans are naturally inclined to sleep at night, and disruptions to this cycle, such as jet lag from traveling across time zones, can affect alertness and lead to feelings of sleepiness at inappropriate times. These hormonal fluctuations play a significant role in regulating overall sense of well-being throughout the day.

Working hours differ for every person according to their occupations. A person working at night

needs to be awake in the night. He/she should be fit and alert enough to perform his task smoothly and without any adverse effect. The effects of nocturnal, morning, and evening light exposure on the hormone production, results in alertness/sleepiness and the synchronization of biological clock. Thus, for functions where people are expected to work at abnormal hours needs to be provided with appropriate lighting which will able to control hue, color, intensity etc. Lighting system is required to be designed in such a way that People working in those areas not only feel alert during duty hours but also able to adjust to their body clock once they are off duty. Biological lighting needs are fulfilled when the lighting supports the circadian rhythm, resulting in good sleep quality, and increases alertness or induces relaxation when needed. The main influential parameters seem to be light exposure (level and duration), spectrum, timing, and spatial distribution and size of the light source. Below Fig. 3 shows the spatial distribution of cortisol, melatonin, alertness, sleep cycle.

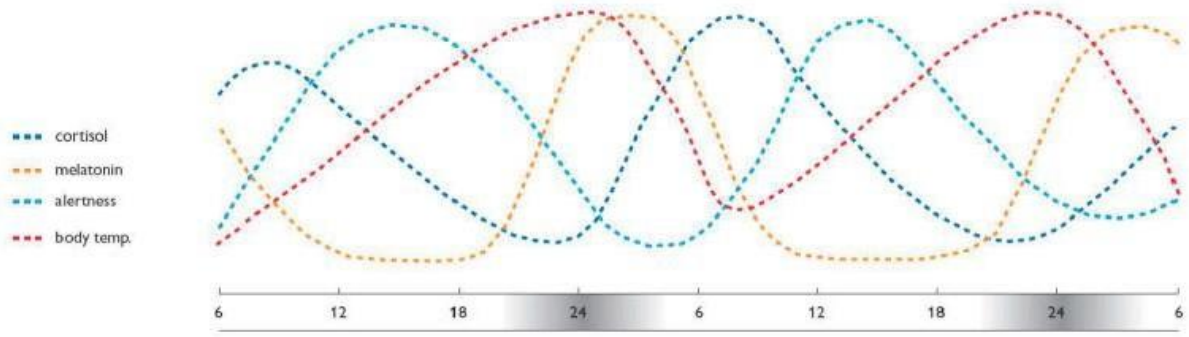


Fig. 3 The Spatial Distribution of Cortisol, Melatonin, Alertness, Sleep Cycle.

4.3.1 *Non-visual Biological Spectral Sensitivity Curve*

The sensitivity of the intrinsic retinal cell also varies with different wavelengths. While observing the sensitivity curve, the difference in the visual sensitivity curve and non-visual biological sensitivity curve can be seen.

Fig. 4 shows the comparison of two curves, ‘Visual’ sensitivity curve for ‘Photopic’ region and ‘Non-Visual’ sensitivity curve. The peak of ‘visual’ sensitivity curve lies in Yellow-Green region and that of ‘non-visual’ sensitivity curve is in Blue region. Thus, light with high color temperature will be thus ‘biologically’ more effective than the source with low color temperature.

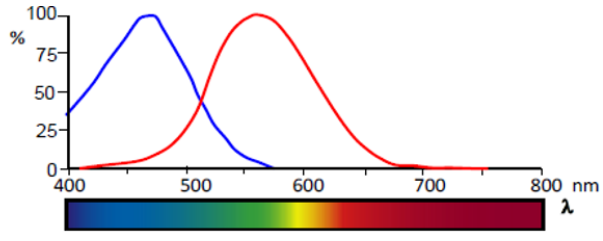


Fig. 4. Spectral Non-Visual Biological Sensitivity Curve Based on Melatonin Suppression.

5 EFFECTS OF LIGHT ON HUMAN BODY

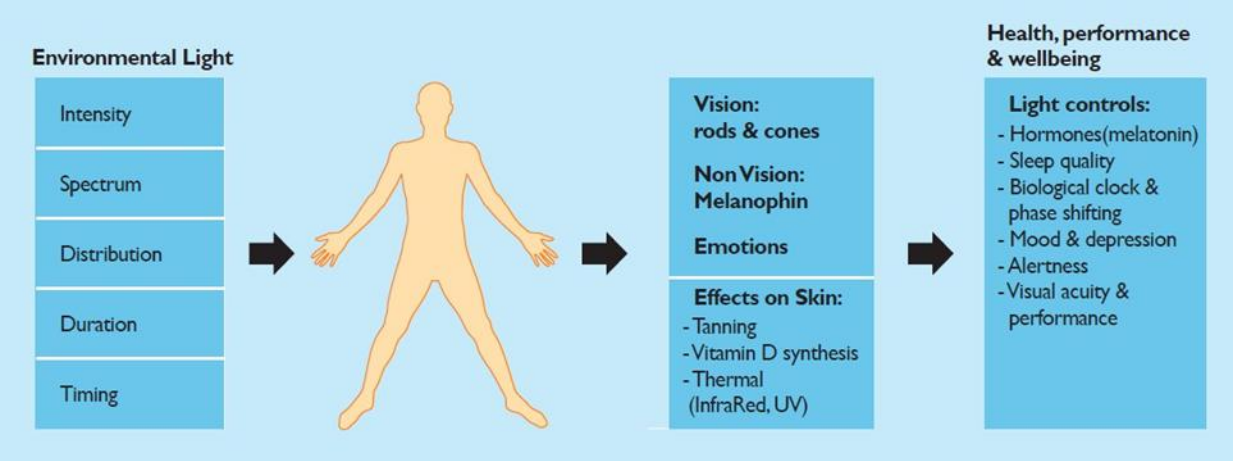


Fig. 5 Effects of Light on Human Body

Over the past few decades, significant advancements have been made in understanding the non-visual or non-image-forming effects of light, as depicted in the Fig. 5. These effects are partially mediated by melanopsin, a novel photoreceptor located in a specific type of retinal cell, which plays a crucial role in regulating the biological effects of light. Melanopsin is most responsive to blue light, with a peak sensitivity at 480 nm. When light is detected by these photoreceptor cells, a complex chemical reaction takes place, producing electrical impulses that are transmitted through separate nerve pathways to the biological clock, which governs the circadian and circannual rhythms of various bodily processes, including hormone production necessary for healthy sleep patterns. Therefore, lighting not only affects our vision, but it also has a profound impact on our overall health, well-being, alertness, and sleep quality.

5.1 Psychological Effects of Light

The psychophysical impacts of light are associated with the visual appeal, ambiance, and overall environmental factors (comprising luminance, luminance distribution, temporal dynamics, chromaticity, and chromaticity distribution within the visual field), which influence our psychological state, emotional experiences, motivation, and affective states.

6 INTEGRATIVE HUMAN CENTRIC LIGHTING (HCL) APPROACH

Incorporating Human Centric Lighting (HCL) principles into a project requires early establishment and serves as a foundation for a comprehensive and collaborative planning process. Designers prioritize natural daylight utilization when possible. The lighting system is then installed and operated based on the HCL plan. HCL implementation involves more than just adjusting illuminance and color temperature, as it considers the overall impact of lighting from a holistic perspective. This encompasses not only visual tasks and biological effects but also the situational context in which lighting is utilized. (*see* Fig. 6).

6.1 Visual

Effective reception conditions are crucial for promoting workplace productivity. To meet this objective, normative and regulatory frameworks establish minimum standards for various activities and workspaces that facilitate visual tasks. The primary goal of the design and operation of these systems is to provide optimal visual conditions for workers. However, individual needs and preferences, such as increased lighting requirements for older adults, must be taken into consideration and customized accordingly

6.2 Emotional

To promote human well-being within their social surroundings, various criteria based on architectural, aesthetic, perceptual psychology, and user expectations must be considered. These criteria adhere to interdisciplinary guidelines and best practices, as they cannot be quantified or found in relevant standards and regulations. Designing a visually appealing room with lighting and formal elements that meet users' expectations can lead to greater user acceptance, satisfaction, and overall well-being.

6.3 Biological

When designing lighting systems, careful consideration and planning of biological impacts is essential, as they significantly affect the human circadian rhythm. Properly planned lighting systems can support the need for increased productivity during the day and improved sleep quality at night. In some cases, lighting can also boost attentiveness and alertness for short period of time

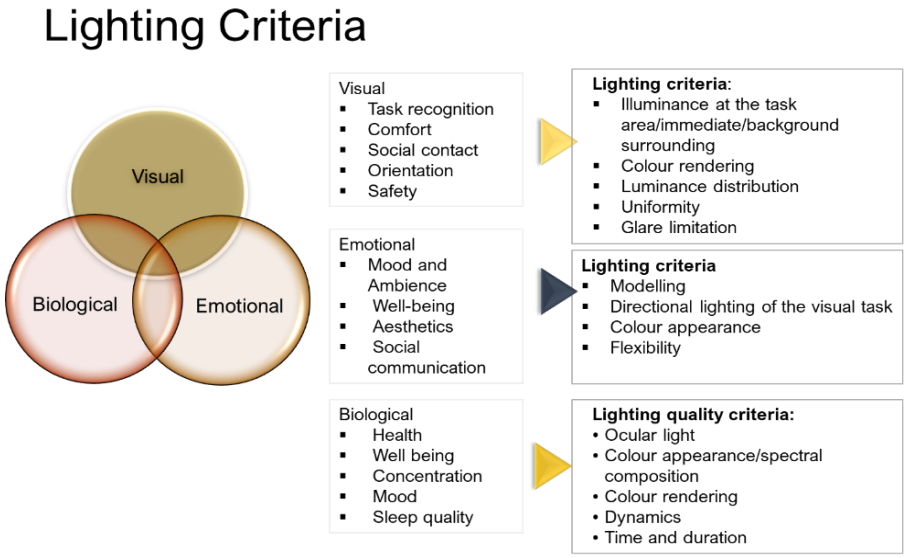


Fig. 6 Lighting Criteria

7 INTEGRATIVE HUMAN CENTRIC LIGHTING (HCL) DESIGN AND OPERATION

When developing an integrative HCL concept, a meticulous and conscientious planning process must take into account all possible effects of light, as they often intersect with one another. For instance, lighting designed to serve a specific visual task will also have biological and emotional impacts. Conversely, a design must not solely prioritize emotional or biological criteria, as it must also meet visual requirements while complying with normative and statutory regulations Compared to conventional static lighting designs of the past, integrated human centric lighting concepts feature dynamic designs and a targeted, long-term perspective.

7.1 Integrative Human Centric Lighting Design Approach

It is crucial to emphasize the key strategies that distinguish Human Centric Lighting (HCL) from traditional lighting design approaches.

a) *Lighting level on task, background and surrounding area* — visual performance is the fundamental for integrated human centric lighting. Lighting level on Task, Surrounding and background should be considered as per the work activity and follow the recommendations as stated in IS 3646.

b) *Spatial lighting and brightness distribution* — spatial brightness is closely related to vision and can also impact psychological perception, such as visual comfort and visual impression. Lighting Level on Walls and Ceiling need to be in proportion to task and surrounding illuminance. Low reflectance factors on walls and ceiling may give a feel of "Dark Room" causing adaptation problems, thus impacting wellness

i) Directionality of light — When designing human-centric lighting (HCL), the direction of light is important to consider. Light should come from above or laterally, to ensure activation of the biologically effective zone of the human eye. Below Fig. 7 shows sensitivity of photoreceptors.

a.

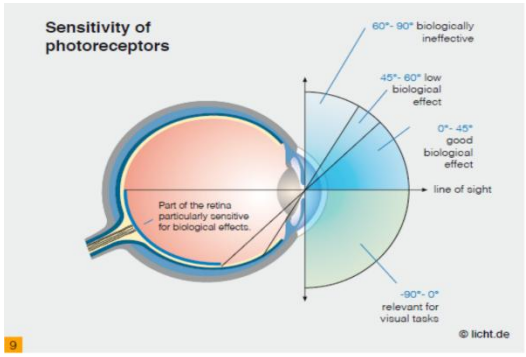
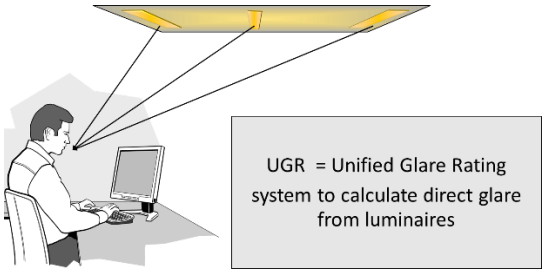


Fig. 7 Sensitivity of Photoreceptors

ii) Glare control —The issue of high-efficacy LED light sources causing glare must be addressed by selecting appropriate luminaires. To evaluate glare, the designer must consider and refer to the current IS 3646. . Glare Evaluation must be evaluated to control both Direct and Reflected Glare by appropriate selection of Unified Glare Rating (UGR), shielding angle and surface brightness of luminaire. Fig. 8 shows calculation of direct glare from luminaires



Lamp luminance	Shielding angle
< 20 kcd/m²	no restrictions
20 – 50 kcd/m²	> 15°
50 – 500 kcd/m²	> 20°
> 500 kcd/m²	> 30°

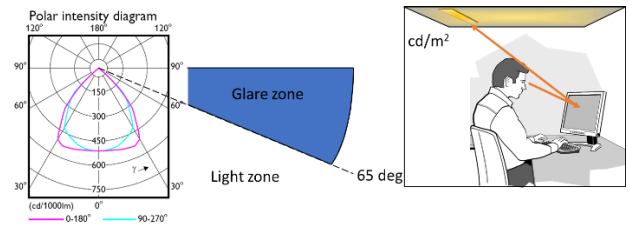
Fig. 8 Calculation of Direct Glare from Luminaires

c) *Spectral composition and colour properties of light source* —

i) The preferred light source should balance the spectral composition with a possibility of Daily and Seasonal variation. Tunable white light is a valuable technology for human-centric lighting solutions. By dynamically adjusting a light source's color temperature and intensity, this lighting can enhance user comfort, productivity, and well-being. Tunable white light enables the creation of dynamic lighting environments that can accommodate varying needs and conditions, optimizing illumination throughout the day and night

ii) Appropriate light sources for such application should be evaluated beyond the classical interpretation of CRI, which is denoted by R a which is average of R1 through R8.In general, good lighting products for indoor work environment applications should have Ra ≥80 and R9 ≥ 0. For human centric lighting, it is recommended that light products should have Ra ≥ 90 and R9 ≥ 50.

d) *Daylight integration* — Daylight defines the parameters for such effective lighting systems in terms of balancing illuminance levels in various zones, its direction of light, spectral composition and dynamism of light over the day and the seasons. Below Fig. 9 shows brightness of luminaire limited above 65º to control reflected glare.



Brightness of luminaire limited above 65 degrees to control reflected glare

Fig. 9 Brightness of Luminaire Limited above 65⁰ to Control Reflected Glare

e) *Flicker and stroboscopic effect* — Flicker and Stroboscopic effect are Temporal Light Artifacts ("TLAs"). TLAs are defined as change in visual perception, induced by a light stimulus, the luminance or spectral distribution, which fluctuates with time for a human observer in a specified environment. Flicker is the perception of visual unsteadiness induced by a light stimulus, the luminance or spectral distribution, which fluctuates with time, for a static observer in a static environment. In other words, it is a disturbing rapid fluctuation of the light in the room. The stroboscopic effect is different than flicker and is defined as the change in motion perception, induced by a light stimulus, the luminance or spectral distribution, which fluctuates with time, for a static observer in a non-static environment. In other words, the stroboscopic effect results in an unnatural break-up of a continuous motion.

i) Flicker — Good lighting products don't show any visible flicker, for a light product to have no visible flicker it should have the flicker metric $P_{st}^{LM} \leq 1.0$ which is based on IEC 610004-15. Measurement of P_{st}^{LM} is done according to IEC TR 61547-1, edition 3. Lighting products with $P_{st}^{LM} \leq 0.5$ are considered excellent in controlling visible flicker

ii) Stroboscopic effect — Good lighting products should have SVM, a metrics that determines the likelihood of a stroboscopic effect occurring, as SVM ≤ 0.9. An SVM ≤ 0.4 is considered excellent in reducing the possibility of stroboscopic effect.

f) *Tunable and dimmable lighting* — In addition to ambiance, a dimming feature paired with a CCT change can positively influence circadian rhythms. Our internal clock, regulated by light intensity and spectrum, dictates wakefulness and sleep. Bright, blue-rich light promotes alertness, while dim, low-blue light triggers melatonin release, inducing sleep. Morning exposure to bright, blue-rich light supports wake fullness, while evening exposure to dim, warm light facilitates undisturbed sleep.

g) *Melanopic EDI* — To optimize non-visual health benefits, workplaces should maintain a minimum melanopic Equivalent Daylight Illuminance (EDI) of 250 lx during daylight hours. This can be achieved through natural daylight, a combination of daylight and electric light, or solely electric light sources, especially when natural light is limited. This approach helps regulate the body's circadian rhythm and supports overall well-

being. The melanopic EDI is measured at eye height in the direction of user’s viewing.

7.2 Recommendations for Users and Effects

The fact sheet should also include details such as:

a) Description of the lighting design concept;
b) Explanation of the control system and user interface;
c) Guidelines for using presets and customization options;
d) Instructions for adjusting light settings and creating new scenarios;
e) Information on how light affects human well-being and productivity;
f) Maintenance guidelines for the lighting system; and
g) Contact information for technical support and service requests.

A comprehensive fact sheet ensures users can maximize their lighting system's benefits and optimize it for their needs, promoting the advantages of human-centric lighting for daily life

7.2.1 *Recommendations* — Recommendations for optimal biological impact include maintaining an illuminance level as suggested in IS 3646 for the respective application and having minimum MEDI of 250 lux achieved on the eye throughout the entire workday. The lighting should also match daylight quality, with a color temperature exceeding 5,700 K until the early afternoon, and potentially shifting to 4,000 K later in the day. It is recommended to use warm white light with a color temperature of 2,700 K or a maximum of 3,000 K, specifically for applications where the goal is to reduce the biological impact of light on human’s circadian rhythm

7.3 Planning Process

A successful HCL lighting concept requires a targeted and expert planning by experienced lighting professionals The user's specific requirements for the such solution must be assessed from an visual, ergonomic, psychological, and biological perspective, and the designer shall develop a holistic concept based on this knowledge. Upon completion of the design phase, the designer creates a documentation package containing the necessary documents for implementing the concept including lighting calculations, visualizations, data sheets, and light scenarios as illustrated in Fig. 10

Light management system (LMS) is commonly recommended to implement an integrative human centric lighting .This allows for personalized control and intelligent data collection. The inclusion of an HCL concept into a design presents a challenge for the designer, as it requires the consideration of parameters such as application usage, building, daylight situation, control, and light technology.

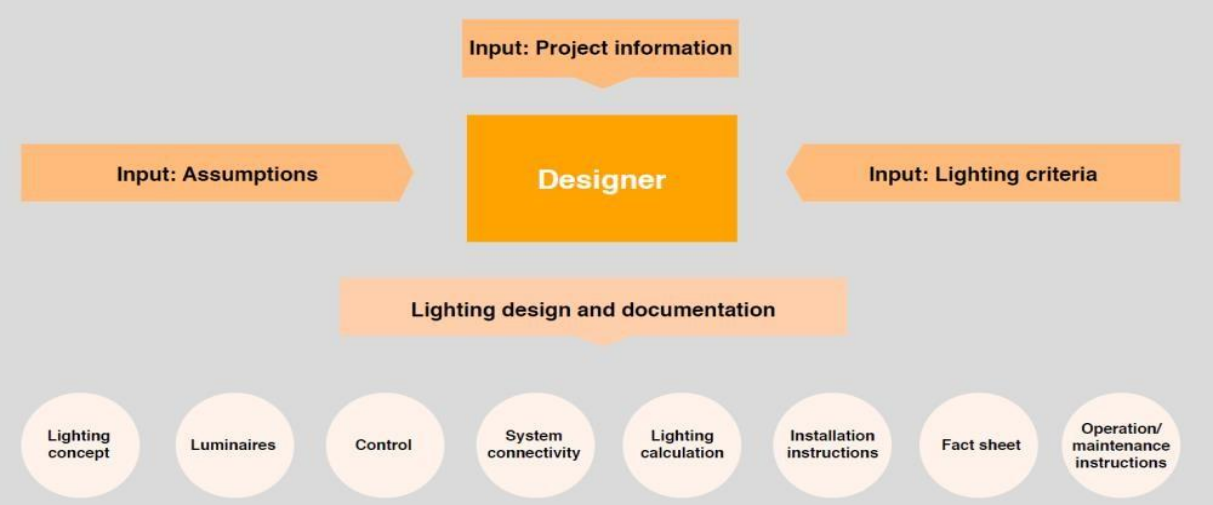


Fig. 10 HCL System

7.4 Planning Parameters

Planning parameters are important for creating a comprehensive and effective HCL lighting plan that meets the specific needs and requirements of the users. By considering factors such as the visual and work tasks of the users, their demographic characteristics, the characteristics of the building and rooms, the light technology and correlations, and the organization and control of the lighting system, the lighting designer can develop a plan that not only supports visual performance but also improves well-being and productivity.

For example, by taking into account the duration and chronological sequence of lighting, the lighting designer can create a plan that gradually adjusts the intensity and color temperature of light throughout the day to support the natural circadian rhythm of the users. By considering the surfaces and objects in the room, the lighting designer can ensure that light is directed to the appropriate areas and tasks while avoiding glare and shadows.

Furthermore, by incorporating advanced control systems, such as motion-dependent control and user-triggered scenarios, the lighting system can adapt to the changing needs and preferences of the users, providing a personalized and comfortable lighting experience.

In summary, by carefully considering these parameters, the lighting designer can create a human- centric lighting plan that enhances the well-being, productivity, and satisfaction of the users.

8 APPLICATIONS OF HUMAN CENTRIC LIGHTING

The lighting design should encompass visual architectural, aesthetic, and psychological aspects, supporting overall well-being. Applications of such integrative human centric lighting can be done in several areas in offices, educational institutes, industries, hospitality, and homes.