

INTERNET OF HUMAN CENTRIC LIGHTING: A BRIEF OVERVIEW ON INDIAN ASPECTS

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Human Centric Lighting is popularly known as lighting for health and better living amongst lighting designers and researchers. It has impact on individual health, behavioural and emotional stability at night that suppress melatonin generation rate. This paper presents a new concept called Internet of Human Centric Lighting by which lighting systems can be monitored and administered by smart internet enabled gadgets for stimulating our work efficiency and relaxation at night to reinforce natural circadian rhythm for a better living environment.

Introduction

Light has an impact on our biological and emotional well being apart from its visual demands. When human beings are the focus of attention in designing lighting, it is known as Human Centric Lighting (HCL). A recent European study revealed that in a factory of 750 workforces, with the introduction of HCL at 2000 lx, the electricity expenses were enhanced from \$47,000 to \$60,000 i.e. by \$13,000 but productivity was also increased by 4.5%. Moreover, 1% lesser casualties were observed due to the rise in alertness which finally resulted in 1% fewer sick days and improved staff retention. A similar study was conducted in an educational institution in Europe amongst 1000 students and 80 teachers. The installation of HCL system enhanced the power consumption from \$8,900 to \$12,240 i.e. to the tune of \$3,340. However, the cognitive performance of some pupils increased upto 15% with 10% reduced healthcare and educational costs of the 5.3% students suffering from

attention deficit hyperactivity disorder (ADHD). The report further assessed extra educational cost per ADHD pupil at \$6,670 but inspite of that it saved around \$667 per student per year. Moreover, it resulted in 18% decrease of mental disorderness amongst staff and reduction of 12 sick days due to stress and finally the attrition rate was reduced upto 2 years. The study further predicted a realistic market penetration for HCL will be 2% for residential use, 5% for repetitive industrial tasks, 10% for education sector, 13% in official jobs, and upto 20% in medical sector by 2020¹.

It is well known that lighting plays a significant role in our daily activities. As we all spend the major portion of work-time under the influence of artificial lighting, hence, their contributions towards health cannot be written-off. The researchers continue their study of lighting on circadian rhythms and contribution of modern day lighting technology for human life development both in the workplace as well as in our home. However, it can not be denied that these pilot studies in controlled environment are still in its early stage and are largely proven practices and strategies which lack in an operational level².

Evolution of Lighting Technologies

Human beings are familiar with natural light source (sun) providing varied intensity and Correlated Colour Temperature (CCT). Eventually, we learnt to make use of fire providing low CCT with reddish glow. Next, we looked

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for some artificial sources of light as most of our time is spent at indoors where sunlight is sparsely available. Initially, incandescent bulb was discovered which was considered as primitive lighting technology with reddish glow (CCT around 2700K). Then, came fluorescent lamp with blue light similar to the colour composition of the outdoor light. Both these technologies have their advantages and disadvantages. The latest technology to create light is Light Emitting Diodes (LEDs') using semiconductor based light source to emit light when activated. When appropriate amount of voltage is applied to its leads, electrons will recombine within device holes to release energy in form of photons. The colour of light emitted by it corresponds to the energy of photon determined by the band gap of semiconductor. The wavelength may vary from red (700 nm approx) to violet (400 nm). Also, some LED sources can transmit infrared energy (830 nm). It emits light from an area lesser than 1 mm² and in the process increase the risk of glare which is minimized by limiting the light source luminance or by increasing background luminance surrounding the light source. Generally, LEDs use 100% of the electrical energy to produce light in comparison with the incandescent bulbs which convert 80% into heat and 20% into light. With such integration of LED based intelligent systems, spectral distribution and lighting dynamics can be properly adjusted to develop an environment which is stimulated and at the same time relaxing for production yield, as well as healthy well-being³.

Photoreceptors of Human Eye

There are three types of photoreceptor cells in human retina, known as ganglion cells, rod cells and cone cells. Ganglion cells and nerve fibres transmit visual information towards brain for circadian rhythm and pupillary reflex action. Rod cells are abundant in nature and light sensitive than cone cells. Human retina comprises of about 120 million rod cells and 6 million cone cells. Rod cells are sensible for vision at low levels (scotopic vision). But, they are not responsible for colour vision and have low spatial acuity, which is because everything is in grayscale at night. On the other side, cone cells are sensible at high light levels (photopic vision) and are used for colour vision. The light level where both the rod and cone cells are functional is known as mesopic vision.

Biological Impacts on Light

As most of the information from environment is perceived from our eye, hence its effect is enormous. Already discussed earlier, there are two parts of retina:

cones are responsible for colour perception and rods are for brightness perception. The visual impression traverses through ganglion cells and optical nerve to emerge at the occipital lobe visual centre.

Circadian rhythm (circa = about, diem/dies = day) refers to the biological processes repeating in our body. Circadian entrainment is the ability to affect our biological clock in forward or reverse direction by endogenous or exogenous processes. The effect of light is influenced by melatonin, which is a photoreceptor in human eye comprising of intrinsically photosensitive retinal ganglion cells (ipRGCs) covering retina like web and is connected with suprachiasmatic nucleus (SCN) directly which acts as the primary clock for circadian rhythms through secretion of melatonin and cortisol hormones⁴⁻⁹. Melatonin or the sleep hormone is produced from the pineal gland to tell the body when it is night for sleep. Its production may get hampered by the stimulation of high intensity light and it gives rise to the production of activity hormone named cortisol leading to poor sleep, indigestion, reduced concentration as well as performance. If the disturbance sustains for a large amount of time it may lead to cardiovascular diseases, obesity, diabetes or even cancer. Even though exercise, social gatherings, scheduled diets can reduce the impact but still it cannot nullify the biological clock disruption from occurring. This may further lead towards reduced activity, emotional break down and depression. Length and quality of sleep is equally important as it increases attention level, has direct impact on memory and performance upgradation¹⁰⁻¹⁴. The circadian efficiency function C-λ curve interms of wavelength along the entire visual spectrum is shown in Fig. 1.

The spectral distribution of light varies throughout the day with short wavelength light during the day and large wavelength light at night. In the morning with shorter wavelength, the melatonin production is blocked which helps us to wake-up. If the reversal occurs, then our sleep will be disrupted and throughout the day we may feel sleepy. Apart from the colour, the intensity also has direct effect on the alertness of people. As human beings have evolved from natural light to artificial light sources, the combined impact of the composition and variation in terms of intensity and colour provides the best functioning model for the people under influence of light. It has been observed in some studies that blue light is required in the morning for waking up, increasing concentration during the day and better sleep in the following night whereas red light is required in the afternoon to keep people activated without hampering the ability to sleep at night. That is why it is not recommended to use mobile phones

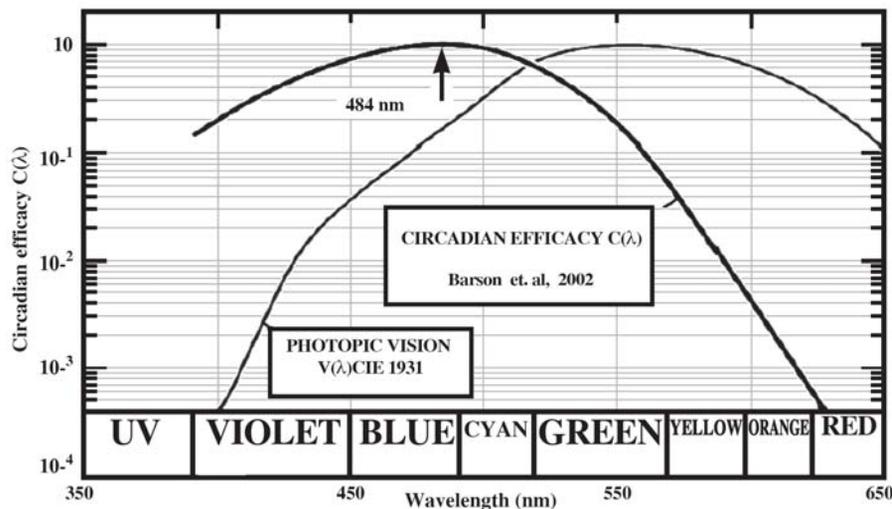


Fig. 1. Circadian efficiency function $C-\lambda$ curve along visual spectrum

at night, as light emitted from mobile screen increases the production of melatonin and disrupts our sleep pattern. Moreover, it has been observed in other studies that too much exposure towards blue light in evening increases the risk of depression. Dynamic colour lighting or HCL will mimic sunlighting pattern using software driven control link for colour and intensity adjustment of artificial light for a healthy life. Proper HCL system leads to visual ergonomics (protect from glare and flickers with proper contrast and reasonable Colour Rendering Index or CRI). Dynamic lighting or HCL system is usually developed using modern day LEDs providing low energy consumption, larger lifetime, lesser heat radiation, and wider colour spectrum. Although this type of lighting system suffers from voltage sensitivity i.e. with the voltage change its lifetime reduces considerably. Simultaneously, cost per lumen will also be increased¹⁵.

Lighting for Mankind: Human Centric Lighting (HCL)

The earth's natural light as received from the sun comprises of low light levels with lower CCT during the day, medium light levels at medium CCT at afternoon, low light levels at low CCT during evening and very low light levels at medium CCT under moonlight. The light levels and CCTs dynamic changes govern our 24-hour internal clock and controls the secretion of different hormones produced inside our body. Dopamine hormone

secretion controls our pleasure, alertness, and muscular coordination. Serotonin is secreted for carbohydrate cravings and impulse control, another hormone called cortisol is secreted for stress response. At night, melatonin hormone is secreted to allow deep sleep and refresh our body. This entire cycle is known as circadian rhythm of human body. If the hormones are not secreted properly then they disrupt the rhythm causing discomfort towards our body. The circadian rhythm or the timing of internal clock of a person is shown in Fig. 2¹⁶.

HCL is comparatively an emerging term which uses to indicate those lighting systems having positive circadian impacts and in the process minimizes light pollution. It takes into account the integration of visual, biological as well as emotional aspects in comparison to its traditional counterparts. Good lighting is not about turning on/off but also to adjust its intensity. Its composition can be varied to create a dynamic lighting environment for better living rather than energy consumption or cost reduction. HCL is not only focussed on circadian entrainment but also to optimize the utility of light in terms of individual, societal and environmental phenomena. The functional and aesthetically pleasing lighting system has a positive effect on cognitive performance including higher concentration, sustained attention, increasing speed of work with higher accuracy and reduced time, fatigue and error rate with enhanced memory functions, emotional quotient (EQ) as well as on chronobiological system. Thus, this newly

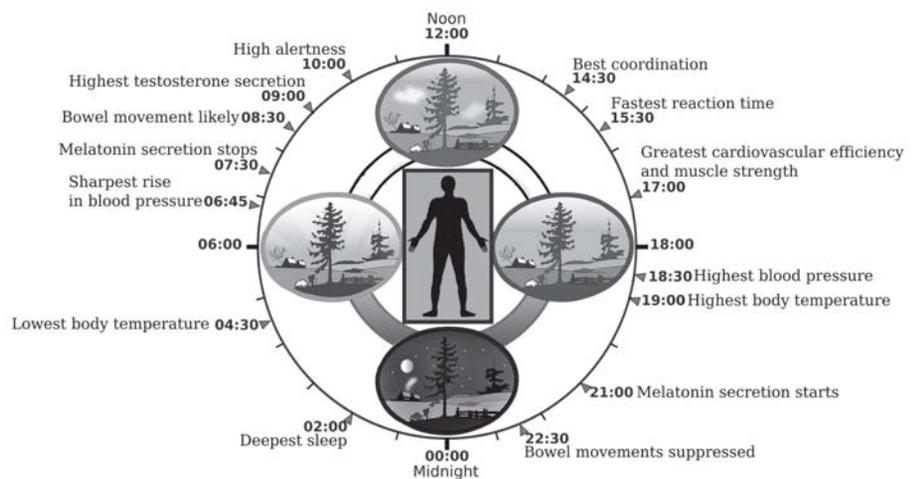


Fig. 2. Human circadian rhythm

developed lighting technology is focussed to ensure the static goal which is right light at right place. In terms of designing HCL systems, the following considerations are to be kept in mind: illuminance level, spatial brightness distribution, occurrence and character of shadows and reflections, glare and last but not the least type, as well as experience of colour of light¹⁷⁻¹⁸.

The global market worth is around \$849 million USD in 2019 with \$395 million USD or 46% of the global revenue is from Europe alone, while North America contributes \$238.3 million USD or 28% of the global revenue and APAC has a share of \$181.7 million USD or 21% of this rapidly growing space. It is expected that it will reach around \$3.5 billion by 2024, having a 32.75% compound annual growth rate (CAGR) over the next 5 years with the companies bringing on innovative products and services to materialize the growth estimation¹⁹.

Possible Implications and Applications of HCL in Indian Scenario

Lighting affects human body in any of the following three ways:

- a. Visual system
- b. Circadian system
- c. Psychological system

Although the visual impacts are measurable but still now the non-visual impacts of HCL such as emotional stability cannot be measured as it is a subjective issue and varies from person to person. However, ‘biophilia hypothesis’ based research affirms that people feel wellbeing when kept closer to the nature. Thus during design, the lighting pattern needs to be dynamic in terms of circadian requirements and emotional responses with suitable light levels at required CCT as mentioned below in Table-1:

Table 1: Features of a HCL system to be maintained throughout the day

Time	Lighting feature
Morning	Lighting should be warm amber during early morning, then to light amber and finally towards white light.
Noon	Lighting should change from white to cool white.
Super	Lighting should change from cool white to white and finally to warm amber again.
Night	Lighting should adapt to various shades of blue through the night.

Lighting for visual acuity or decorative purpose only is nowadays no longer acceptable. The previous trends of energy efficient lighting have been shifted towards human centric energy efficient lighting approach. Hence, lighting shall be such that it is friendlier to the circadian clock²⁰⁻²¹. HCL is considered to be applicable mostly in indoor lighting conditions where the lux levels are within 1000 lux and having CCT from 3000K-6500 K. In outdoor lighting conditions when eye is sensitive to lower lux levels under mesopic condition, safety and vision become the most important factor.

Mindtree’s Network Operations center in Bangalore is developed keeping HCL in mind. However, a collective effort is required from all the stakeholders to give its entry just like daily dosage of tea or coffee²². HCL systems are installed in schools with sufficient brightness and blue enriched to keep teachers and pupils calm, concentrated and alert during school hours. In commercial workplaces, HCL makes the office environment more natural and comfortable to increase the productivity yet maintaining the job satisfaction of workers. In healthcare sector, HCL is incorporated with cooler CCTs to make the staff less fatigue, alert, provide them with better performance, precision as well as increased safety during shifts and warmer CCTs where patients are kept for comfort as they rest and recover from illness or stress due to modern lifestyle. HCL systems can add their benefits into hospitality and wellness sector as well to help visitors feel more comfortable, reduce jet-lag, and make rooms more elegant, ease of control with lower energy consumption, heat generation, operational expenditures and maintenance requirements. Systems which are installed in India use LEDs in their solutions providing larger lifetime with high CRI, zero maintenance, ease of installation and controllable through RF remote while conforming to IEC standards.

Under the Smart City scheme from Government of India, total 10459.2 crores of money has been released upto March 2018 to convert one city into a smart city which estimates an impact on 9,96,30,069 urban population. Out of 100 winning proposals, the total project cost under this scheme is 2,05,018 crores, total area based development cost is 1,64,204 crores and total pan city solution cost is 38,914 crores²³. Under this scheme, if HCL based LED luminaries can be installed, their impacts can be investigated. India’s LED market is projected to grow from \$ 918.70 million in 2016 to \$ 3,758.74 million in 2020, i.e. at a CAGR of 24.66%. According to a study, 2.54 billion smart lighting units will be installed by 2020 and smart lighting solutions are set to become the most frequently used home automation feature²⁴⁻²⁵.

Presently, HCL is in nascent stage in India but opportunities galore as the scope for enhancement is huge due to its population and developing economy. The government of India launched a scheme named “Domestic Efficient Lighting Programme (DELP)” in 2015 which was renamed as Unnat Jyoti by Affordable LEDs for All (UJALA) by which people could buy affordable LED bulbs instead of incandescent or CFL bulbs, and mercury tubelights by which 25 crore households were benefitted as on date²⁶. Street Lighting National Programme (SLNP) was launched by EESL (Energy Efficiency Services Limited) by which more than 21 lakh street lights were installed across 23 states and union territories. 230 million LED bulbs, 8 lakh energy efficient fans, and 203 million LED tubelights helped in saving 32 billion kWh of electricity annually and have reduced consumption of 19 million tonnes of coal which is equivalent to an annual reduction of 25 million tonnes of CO₂ and is further equivalent to 600 million trees over a period of ten years. Consumers under this scheme saved around 124 billion INR annually on their electricity bills. This further led to increase in production of LED bulbs nationally and thus reduced the price of the bulb by leaps and bounds²⁷. The present government’s ‘Make in India’ initiative has been instrumental in stimulating the smart HCL systems demand in this part of the globe. It is aimed at enhancing vision, well-being and performance by serving in-depth knowledge to evoke particular human biological responses²⁸. According to a research made under ‘Make in India’ initiative, it has been observed that about 25-30 people per minute migrate from rural areas in search of better livelihood and developed lifestyles. With this momentum, it is estimated that 843 million people will live in urban areas by 2050 and cities with human centric design approach will evolve from being smart towards responsive, hence the citizens will move from the centre of attention towards the centre of action²⁹.

Internet of Human Centric Lighting

The application of internet for monitoring of all the devices connected is known as Internet of Things. Similarly, lighting systems can also be connected over internet and be named as Internet of Smart Lighting (IoSL). They can be controlled using modern day wireless communication protocols. Thus, the light intensity and colour of light may be changed as per the requirement of user and hence, it can be considered under Internet of Human Centric Lighting (IoHCL). Philips HUE supported by ZigBee or dimmable DALI (digital addressable lighting

interface) version from Osram can be considered as a similar concept which has the ability to tune any lighting product based on intensity and colour combinations. Also, Indian companies like Luminous Power, Syska, Legrand, Dominto Dyna from Bajaj Electric, Wipro Lighting provide affordable HCL solutions at a fraction of the overall cost without installation of separate ambient lights³⁰⁻³². As it is expected that 20 billion devices are to be connected with internet, hence, wireless networked lighting is going to increase at a CAGR of 23% and thus make a large impact across the world. These lighting solutions may either be integrated with non-sensor programmable lighting systems or sensors capable of adjusting the luminosity of light automatically. It is estimated to save upto 40% of the energy consumed by reaching 37% of the smart streetlight market. Wipro lighting has been remotely controlling over 10,000 lights in a smart city using Power over Ethernet cables and was planning to launch Lifi (light fidelity) based wireless communication between lighting solutions to transmit positional data, in assistance with Scotland-based pureLiFi which will stimulate energy and alertness, thus improving cognition and emotional stability³³⁻³⁵. Using Electroencephalography (EEG) and Electrooculography (EOG), the performance of human body in adopting different lighting technologies under various conditions can be compared and a smarter lighting system can be developed. Indoor smart lighting is estimated to grow at a CAGR of 25% by 2025 driven by reduction of energy consumption with the increasing population. Typically, lighting is about 40% of a building’s energy requirement and IoSL or IoHCL can reduce the energy consumption and lead upto 80% savings from energy usage and mitigate operational expenses³⁶⁻³⁷.

Conclusion

As the concept of HCL system is comparatively new in this part of the world, hence, customer detailed review report may not be available easily. Sometimes, the lesser important points happen to obtain greater importance and it entirely depends upon the application area, type and time of usage. Hence, a new concept called Internet of Smart Lighting or Internet of Human Centric Lighting is proposed. This new concept of lighting installation may enhance the project capital investment by a fraction but definitely reduce the operational expenses with an increase in environmental impacts. HCL system will work well in workplace relating to academics, research or places where light is an important parameter to be taken under consideration. This new concept of lighting arrangements will slowly but surely find a space from reputed places to every household in times to come. □

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