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HEALTHCARE LIGHTING:
A Guide to Practitioners

Editorial

This document should be referenced as:

Healthcare Lighting: A Guide To Practitioners

For more information

info@cedro-undp.org

UNDP Country Entrepreneurship for Distributed Renewables Opportunities project management team

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Lead author

Engineer Rabih El Medawar

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List of Acronyms	
ANSI	American National Standards Institute
BS	British Standard
CCT	Correlated Color Temperature
Cd	Candela
CoB	Chip on board
CT Scan	Computerized Tomography Scan
CFL	Compact Fluorescent Light
CRI	Color Rendering Index
CIBSE	Chartered Institution of Building Services Engineers
E27	Standard 27mm diameter screw cap for 240V light bulbs
EN	European Norm/Standards
Ff	Failure fraction
Kfw	KfW Development Bank
kWh	kilowatt hour
GUV	Germicidal Ultraviolet
HID	High Intensity Discharge
HVAC	Heating Ventilation Air Conditioning
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America

IEC	International Electrotechnical Commission
IP	Ingress protection
LDC	Luminous Intensity distribution Curve
LED	Light emitting diode
lm	Lumen
Lux	Illuminance
MRI	Magnetic Resonance Imaging
MWh	Megawatt hour
PAS	Public Available Specification
PET Scan	Positron Emission Tomography Scan
Ra	Color Rendering
RHUH	Rafik Hariri University Hospital
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
S4H	Solar for Health
SMD	Surface Mounted Device
T(q)	Ambient temperature
UGR	Unified glare rating
UNDP	United Nations Development Programme
UV	Ultraviolet
W	Watt

1. Healthcare Lighting Overview

Healthcare facilities have the potential to play a major role in the transition towards a more sustainable world. Reducing energy consumption and carbon emissions while improving staff experience and patient comfort is the current challenge healthcare facilities operators are facing.

Modern lighting solutions reduce costs by saving energy without compromising comfort and light quality, inversely modern lighting solutions can improve comfort, quality while simultaneously reducing environmental impacts. State of-the-art light emitting diode (LED) technology and control systems can also reduce installation, operation, and maintenance costs, allowing scarce resources to be allocated to other vital areas.

As lighting plays a major role in reducing power consumption and carbon emissions, this document serves as a guideline for healthcare facilities and highlight the requirements of modern healthcare lighting practices which focus on sustainability and human comfort.

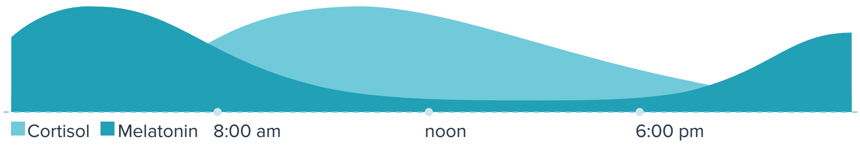
1.1. The Concept Of Human Centric Lighting

Light influences human's health and wellbeing. In fact, a growing body of research and information is available on the impact of lighting on people, and particularly its effect on emotions, wellbeing and workplace productivity (Juslén, 2016). A clear and positive relation exists between patients exposed to sufficient light during the day and their health and wellbeing. The more time is spent in daylight, or artificial light mimicking natural daylight, the better it is for the healing process. Light improves mood, satisfaction, comfort, and quality of sleep (Philips, 2011).

Light has a considerable effect on human's biological clock as it influences both the physical and the emotional wellbeing. The body's biological clock is regulated by light and darkness, by the daily cycles of day and night and by the time spent awake and asleep.

Waking up in the morning when the sun is up, and the light levels have increased renders the person active and alert. While at sundown, the body unwinds and relaxes in preparation for sleeping. The body's hormone levels change with the light cycles as cortisol production increases in the morning and decrease throughout the day and melatonin levels increase with darkness and decreases as morning comes. This natural internal process that regulates the sleep-wake cycle and repeats roughly every 24 hours is called the circadian rhythm - see Figure 1 (NICHD, 2019).

Those who spend too much time indoor, like hospital patients or staff, are at the risk of getting insufficient light during daytime to properly set the biological clock (Philips, 2011) and avoid an imbalance in the hormones production.



Night
Have a good night sleep
- Lowest light levels
- Undisturbed sleep

Dawn
A good start in the morning
- Cool increasing light levels
- Raise the energy level

Day
Have a break and refresh
- Cool to warm light decreased light levels

Dusk
Relax and unwind
- Warm light, decreased light levels
- Start melatonin production

Figure 1 - Circadian Rhythm (Source: Philips, 2011)

Human centric lighting is the art of creating lighting that mimics the natural daylight which drives our bodily functions. It enhances human performance, comfort, health and well-being (OSRAM, n.d.).

Taking into consideration the effect of light on the human body, a human centric lighting approach should be holistic and application oriented. It should balance visual, emotional, and biological needs of humans in the lighting application.

1.2. The impact of lighting on healthcare workers and patients

Studies have shown that lighting has always been linked to patients' speed of recovery and mental health (Anjali, J. 2006). Figure 2 shows how vision, psycho-emotional responses and non-visual or non-image forming effects affect performance, well-being and health.

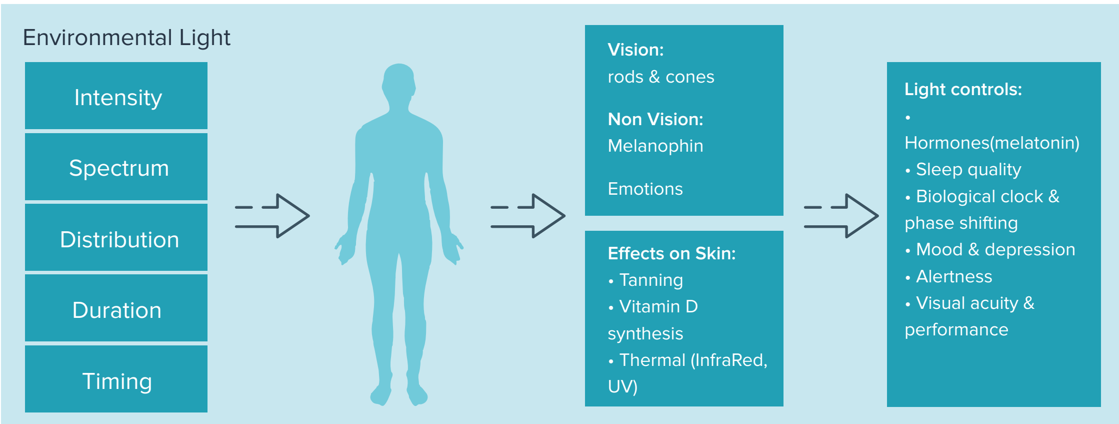


Figure 2 - relation between light, vision and Health (Source: Philips)

The most obvious effect of lighting is enabling vision and performance of visual tasks. As age increases, the need for light increases. With increasing age, the eye lens transmittance changes. The lens becomes more scattering and yellow. Elderly people (70-80 years) need about ten times more light to achieve the same visual performance as compared to middle-aged people (45-55 years) (Geerdinck et al , 2009). Many elderly people report being forced to stop playing cards or doing needlework due to poor sight. In many cases this is unnecessary, as extra light would have improved their visual performance, thus enabling them to remain engaged in social activities longer.

Both natural and artificial lights influence many health outcomes, e.g., by reducing depression, improving sleep and circadian rest-activity rhythm, easing pain and shortening the stay in the healthcare facility.

Physical and psychological health is impacted by poor sleep quality. Disturbed sleep can affect personal well-being and impede the rehabilitation and recovery of older people from illness. Strengthening the endogenous circadian rhythm by providing sufficient daytime illumination and activities can be expected to be of clinical relevance (Philips, 2010).

Surveillance of infants in intensive and medium care facilities also needs adequate lighting and lighting cycling as providing an environment that supports an infant's emerging organization and behavioral integration enhances the ability of the infant to respond appropriately to his or her parents. It also helps in coping with the home environment after discharge.

Lighting also helps in improving the quality of life for the patients living with the impact of dementia: reducing nocturnal restlessness, depression and cognitive decline.

Many spaces in a hospital have no direct natural light. Dynamic solutions can be applied to develop a sense of connection to the outside world for the staff. Such solutions will use the dynamic characteristics of daylight to enhance wellbeing, performance, and motivation. By giving the staff the ability to control lighting and create stimulating lighting ambiance, for example by changing the level and tone of white light, it makes it possible to simulate natural lighting hence helping professionals perform more effectively. Lighting can be designed in a way to boost alertness and concentration levels, e.g., on the night shift.

Finally, in laboratories, pharmacies, and offices, where optimum lighting is a necessity due to the required precision and attention to detail, these settings demand high-quality lighting to foster a productive and comfortable environment.

1.3. UV Light in healthcare (post covid 19 recommendations)

The COVID-19 pandemic has underlined the importance of adopting effective infection prevention and control measures in hospitals. Ultraviolet based technologies represent promising tools: their effective application for sanitation has been extensively evaluated in the past but scant, heterogeneous and inconclusive evidence is available on their effect on SARS-CoV-2 transmission. Recent studies showed that advances in UV-based technologies in the field of sanitation and their proven high virucidal potential against SARS-CoV-2 support their use for infection prevention and control in hospital and community settings and their contribution towards ending the COVID-19 pandemic (Chiappa, 2021).

Non-contact disinfection technologies are highly desirable, and UV radiation, in particular UV-C (200-280 nm) has been suggested to be able to inactivate different viruses, including SARS-CoV. The interaction of UV-C radiations with viruses has been extensively studied, and direct absorption of the UV-C photon by the nucleic acid basis and/or capsid proteins leading to the generation of photoproducts that inactivate the virus was suggested to be one of the main UV-C-associated virucidal mechanisms (Mara Biasin, 2021).

1.3.1. What is UV-C?

UV-C is part of the ultraviolet spectrum, shown in Figure 3 below, that can inactivate pathogen like bacteria and viruses. UV-C utilizes specific wavelengths of the Ultraviolet spectrum, typically between 200 and 280 nanometers.

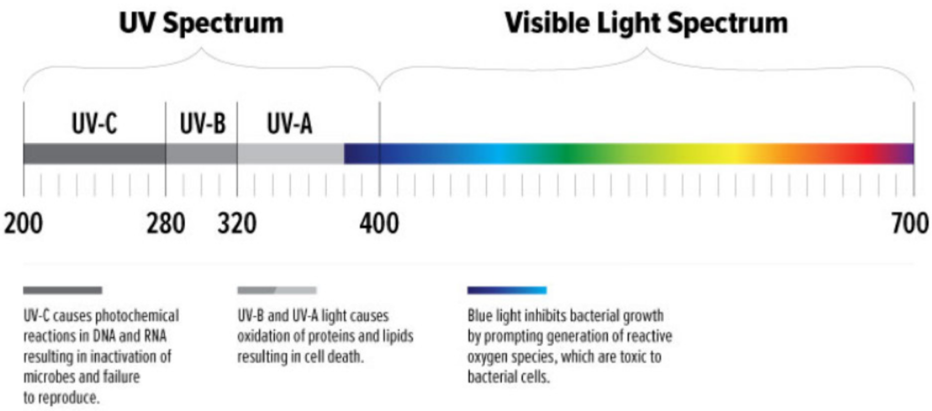


Figure 3 - UV and Visible Light Spectrum (Source: Regency Lighting)

A recent IES (Illuminating Engineering Society) committee report entitled "Germicidal Ultraviolet (GUV) - Frequently Asked Questions" stated recently that UV-C can effectively inactivate the SARS-CoV-2 virus, responsible for COVID-19 but it is essential that individuals be protected to prevent UV hazards to the eyes and skin.

The same report concluded that germicidal ultraviolet (GUV) applications - See Figure 4, can be used to reduce the spread of airborne infectious diseases such as tuberculosis, influenza virus, measles, SARS, and, presumably, SARS-CoV-2.

It is also a recommended application for healthcare facilities to reduce transmission by including upper room GUV systems to supplement ventilation measures. Furthermore, using GUV in air handling units of existing HVAC systems is recommended in addition to suspending an open UVC fixture at a height greater than 12 meters in the event of a pandemic. This would cover both air and surface but would require personal protection of patients and health workers. GUV LEDs are being tested for both upper air disinfection and for some surface disinfection. This is a promising area of research and should be considered as further data becomes known.

Figure 4 - Example of GUV lights (Source: Regency Lighting)

1.4. Principles of Quality Lighting, Task Visibility, Glare, and Color

Quality of light plays an essential role in creating healthcare spaces that address both the clinical and emotional needs of patients, family and staff. Good quality lighting design can create human scale intimacy and areas of privacy, enhance colors and surroundings, prevent furnishings & surfaces from looking dim, highlight sparkling clean, encourage soft speaking and overall quiet with lower light levels, minimize disturbance due to noise, create soothing, relaxing environments, lower stress reduces need for pain medication welcome and put people at ease, improve wayfinding, enhance safety and security and create positive brand position.

The quality characteristics of lighting have been evolving and, in addition to the traditional quality criteria, new quality criteria have been added. Traditional quality criteria included the following:

- Sufficient illumination level
- Harmonious brightness distribution
- Glare limitation
- Avoidance of reflections
- Good modelling
- Correct light color
- Appropriate color rendering

As for the new lighting quality criteria:

- Changing lighting situations
- Personal control
- Energy efficiency
- Daylight integration
- Light as an interior design element

1.4.1. Basic parameters used in lighting - Definition of terminologies

The basic parameters used in lighting are defined below and shown in Figure 5 (Zumtobel, 2018):

- **Luminous flux** (Unit: lm Lumen)

The luminous flux describes the quantity of light emitted by a light source. The luminous efficiency is the ratio of the luminous flux to the electrical power consumed (lm/W). It is a measure of a light source's economic efficiency.

- **Luminous intensity** I (Unit: cd Candela)

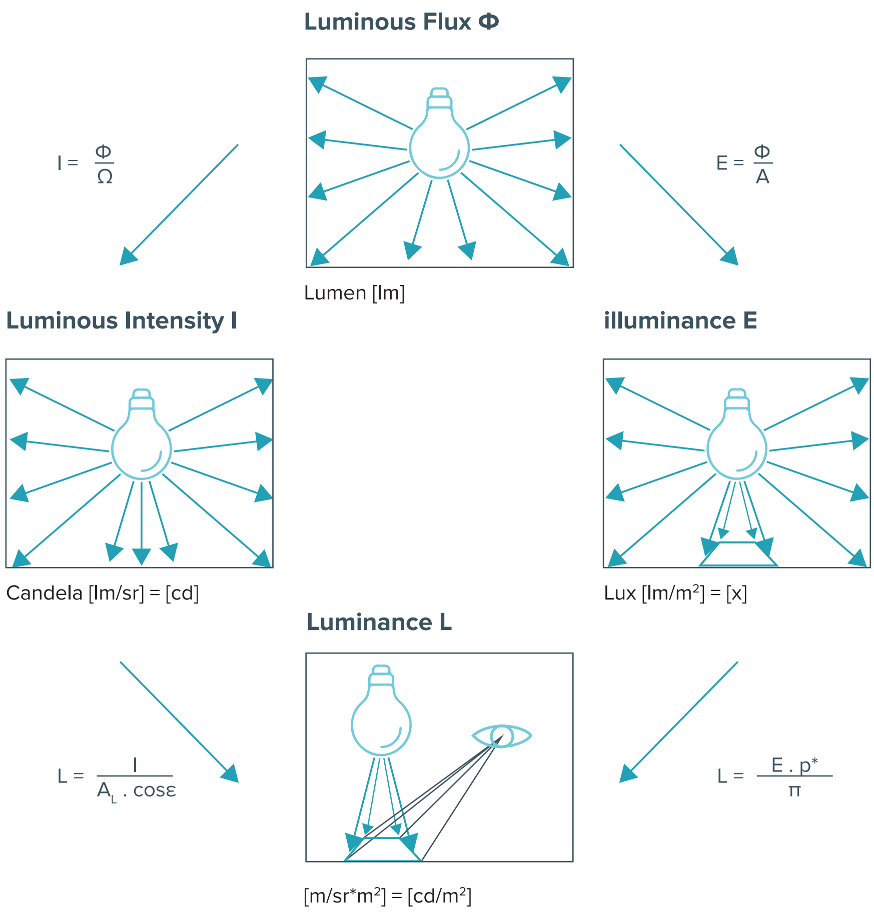
The luminous intensity describes the quantity of light that is radiated in a particular direction. This is a useful measurement for directive lighting elements such as reflectors. It is represented by the luminous intensity distribution curve (LDC).

- **Illuminance E** (Unit: Lux)

Illuminance describes the quantity of luminous flux falling on a surface. Relevant standards specify the required illuminance (e.g. EN 12464 "Lighting of indoor workplaces").
Illuminance: E(lux) = luminous flux (lm) / area (m2)

- **Luminance L** (Unit: cd/m2)

Luminance is the only basic lighting parameter that is perceived by the eye. It describes on the one hand a light source's impression of brightness, and on the other, a surface and therefore depends to a large extent on the degree of reflection (color and surface).



Ω = solid angle into which luminous flux is emitted
A= area hit by luminous flux
A_L . cosε = visible areas of light source
ρ = reflectance of area
π = 3.14
* = for diffuse surface areas

Figure 5 - Luminous flux, Luminous Intensity, Illuminance and Luminance (Source : Zumtobel,2018)

- **Visual task area**

Illuminance levels are specified for specific visual tasks and are designed for the area in which these may take place. If the exact location is unknown, the room as a whole or a defined area of the workstation is used for specification. The visual task area may be a horizontal, vertical or inclined plane.

- **Illuminance maintenance value Em**

Value below which the illuminance level must not fall in the visual task area.

- **Maintenance factor**

The initial value multiplied by the maintenance factor gives the illuminance maintenance value. The maintenance factor can be determined individually and takes the installation’s reduction in luminous flux caused by soiling and ageing of lamps, luminaires and room surfaces into account. The maintenance schedule (the cleaning and maintenance intervals for the lamps and installation) must be documented.

- **Uniformity UO**

In order to perform visual tasks in illuminated areas, there should not be any great differences in brightness so that uniformity should not fall below UO= Emin / Eaverage

- **Reflectance factors**

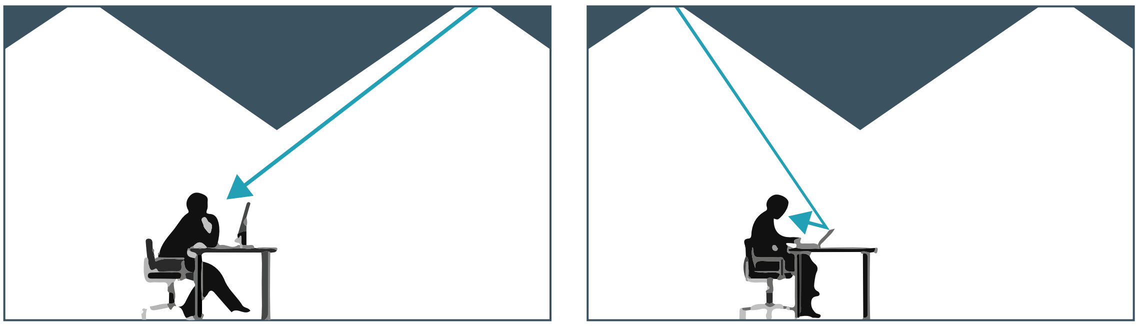
The reflectance factors of the room and object surfaces determine not only the perception of the room but also the reflected light and thus the room's brightness.

- **Glare**

Glare is luminance within the field that is sufficiently greater than the luminance to which the eyes are adapted that cause annoyance, discomfort, or loss in visual performance and visibility.

  - Direct Glare: is glare resulting from high luminance or insufficiently shielded light sources.
  - Disability Glare: is the effect of stray light in the eye whereby visibility and visual performance are reduced.
  - Discomfort Glare: does not necessarily interfere with visual performance or visibility but produces discomfort.
  - Reflected Glare: is glare usually from specular reflections of high luminance in polished or glossy surfaces in the field of view.

Figure 6 shows the direct and Indirect glare causes, effects, and remedies:



Cause

- Luminaires without glare control
- Very bright surfaces

Effect

- Loss of concentration
- More frequent mistakes
- Fatigue

Remedy

- Luminaires with limited luminance levels
- Blinds on windows

Cause

- Reflective surface
- Incorrect workstation position

Effect

- Loss of concentration
- More frequent mistakes
- Fatigue

Remedy

- Matching luminaire to workstation (layout)
- Indirect lighting
- Matt Surfaces

Figure 6 - Direct and Indirect Glare: Causes, effects, and remedies (Source: Zumtobel,2018)

Glare Evaluation: UGR method is used to regularly evaluate luminaires in a room as specified in the standard EN 12464-1 “Lighting of indoor workplaces”. The standardized UGR method (unified glare rating) is used to assess (psychological) glare. The UGR value is calculated with a formula:

$$UGR = 8 \log \left(\underbrace{\frac{0{,}25}{L_b}}_{(1)} \underbrace{\sum \frac{L^2 \Omega}{P^2}}_{(2)} \right)$$

Where:
(1): Brightness of walls and ceilings.
(2) as well as all luminaires in the system that contribute to the sensation of glare.
The result is a UGR index. The UGR limits are specified in the EN 12464 standard for activities and visual tasks (refer to section 2.c for healthcare lighting UGR limits).

- **Light color/temperature (CCT):** is the color appearance of the light (see Figure 7). There is no right or wrong correlated color temperature to be used in healthcare. the key is maintaining a consistency in the appearance by using light sources with the same CCT and CRI abilities. Inconsistencies in the color temperature are noticeable when light sources of different colors are located in the same visual field (IES, 2020).

Figure 7 - Different color temperature appearance (Source: Premium Beat)

- **Color rendering (CRI):**

The ability of a light source to reproduce surface colors (8 test colors R1 to R8) faithfully compared to a reference light is called color rendering and identified by the color rendering index (CRI). A color rendering of Ra=100 is the best.
Light sources are divided up into color rendering levels:

- Ra > 90 very good color rendering
- Ra > 80 good color rendering

Color rendering of less than 80 should not be selected at workplaces. However, when used in exceptional cases, if a light source has a CRI below 80, it has to be ensured that safety colors can be recognized. Additionally, the saturated test colors R9 to R14 are also used occasionally to describe special functions of a light source. The reproduction of these colors is then quoted separately (see Figure 8).

Figure 8 - R1 to R14 colors (Source: Zumtobel,2018)

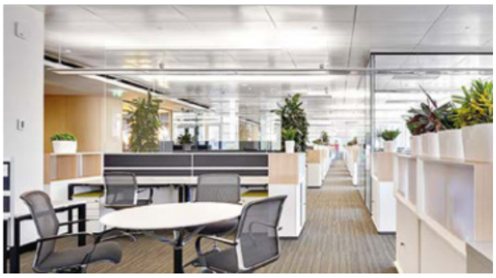
High R9 factors are now important for healthcare staff when they are assessing skin color of patients because the color red is prevalent for the eye to interpret more pure colors. Color is a type of diagnostic indicator as medical staff use this indicator in body areas like the eyes, skin, nails, to assist in physical diagnosis, lab specimens' observation and color of pills and fluids. maintaining a good CRI supports work performed in a healthcare facility.

1.5. Types of lighting:

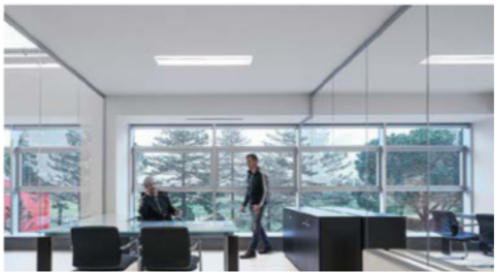
- **Direct Lighting:** is when lighting falls directly from the light source on the ceiling to the task area or workplace. In this type of lighting, a "cave effect" may appear making the ceiling look dark. Care should be given to the layout of the area elements to avoid shadows. High energy efficiency is achieved when using direct lighting as reliance on reflection is minimal.

- **Indirect lighting:** is when light is directed towards walls and ceilings so that illuminates the target area indirectly. This type of lighting will increase the room height and is glare free. Minimal shadows will make the work area flexible for arrangement. Low energy efficiency is achieved using this type of lighting.

- **Indirect/Direct Lighting:** is when lighting is a combination both direct and indirect, via the ceiling or from free standing luminaires, this gives a pleasant room visual, has a high user acceptance and good contrast ratios. As the indirect light share increases, flexibility increases. This type of lighting allows a combination of good lighting quality and energy efficiency.



- **Mellow light:** is when the advantages of direct and indirect lighting are combined in a ceiling mounted luminaire. This is a glare free approach with a high acceptance. It gives a daylight impression and combines energy efficiency and lighting quality.



2. Healthcare Lighting Needs

A unique and complex set of challenges are presented for lighting designers working on a healthcare sector facility. This is due to the variety of tasks that are performed, the different users, usage duration and the necessity to integrate lighting in the overall setting of a healthcare facility. The on-going technological advancements present the lighting designer with exciting opportunities to provide the best possible lit environment considering the user, infection control, compliance and sustainability.

2.1. Design Considerations

Beyond obvious factors, i.e. luminaire light distribution, size and location, when designing the lighting system, the following should also be taken into consideration:

- Building orientation for optimum daylight ingress and the beneficial effects of sunlight
- Necessary sun screening for both performance and comfort of the staff and patients
- Light distribution and possible detrimental effects of glare from interior surfaces
- The lit appearance: its quality and its ability to enhance the medical purpose
- Lines of sight effect for both staff and patients
- Illumination of specific areas or tasks
- Emergency and essential lighting needs
- Interior design intentions
- Patient journey
- Light source selections (its color temperature and color rendering properties)
- Choice of light source control
- Potential for energy efficiency
- Control, maintenance and cleaning of the luminaires
- Easy and safe access to lighting
- Equipment and windows for cleaning and maintenance
- Coordination with other services and equipment
- Appearance of the luminaire and its integration with the architecture.

The illumination of all surfaces is important, and it is not always sufficient to just light the surfaces that form the major part of the field of view. Lighting must contribute to an overall ambience of comfort, safety and reassurance for patients and staff. This is particularly relevant to entrance halls, reception and circulation areas. These are the areas where patients and visitors will gain their first impressions of the building (CIBSE, 2019).

When using indirect lighting as a source of general room illumination, reflectance values of surfaces within the room will generally need to be higher than for downlight arrangements. If reflectance values are known at the design stage, then they should be used. Account should be taken at the design stage that the appearance and ambience of a building interior at night can be very different from those experienced during the daytime.

Light color has a vital role in enhancing the healthcare environment and providing information and orientation. It helps occupants make sense of their spaces and feel better about their environment. Visitors get encouraged to feel positive about their experiences and staff can appreciate their workplace.

2.2. Illumination levels

The following general lighting schedule gives, in tabular form, recommendations for the illuminance requirements for the different departments and rooms in hospital and healthcare buildings (see Table 1):

Type of task or activity	Em	UG RL	Ra	Type of task or activity	Em	UG RL	Ra
Rooms for general use				**Treatment rooms (general)**			
Waiting rooms	200	22	80	Dialysis	500	19	80
Corridors (during the day)	200	22	80	Dermatology	500	19	90
Corridors (at night)	50	22	80	Endoscopy rooms	300	19	80
Day rooms	200	22	80	Plaster rooms	500	19	80
Staff rooms				Medical baths	300	19	80
Staff office	500	19	80	Massage and radiotherapy	300	19	80
Staff rooms	300	19	80	**Operating areas**			
Wards, maternity wards				Pre-op and recovery rooms	500	19	90
General lighting	100	19	80	Operating theatre	1000	19	90
Reading lighting	300	19	80	**Intensive care unit**			
Simple examinations	300	19	80	General lighting	100	19	90
Examination and treatment	1000	19	90	Simple examinations	300	19	90
Night lighting, observation lighting	5	-	80	Examination and treatment	1000	19	90
Bathrooms and toilets for patients	200	22	80	Night watch	20	19	90
Examination rooms (general)				**Dentists**			
General lighting	500	19	90	General lighting	500	19	90
Examination and treatment	1000	19	90	At the patient	1000	-	90
Eye examination rooms				Operating cavity	5000	-	90
General lighting	300	19	80	White teeth matching	5000	-	90
Examination of the outer eye	1000	-	90	**Laboratories and pharmacies**			

Reading and colour vision tests with vision charts	500	16	90
Ear examination rooms			
General lighting	300	19	80
Earr examination	1000	-	90
Scanner rooms			
General lighting	300	19	80
Scanners with image enhancers and television systems	50	19	80
Delivery rooms			
General lighting	300	19	80
Examination and treatment	1000	19	80

General lighting	500	19	80
Colour inspection	1000	10	90
Decontamination rooms			
Sterilisation rooms	300	22	80
Disinfection rooms	300	22	80
Autopsy rooms and mortuaries			
General lighting	500	19	90
Autopsy table and dissecting table	5000	-	90
Em - Illuminance (Lux) **UGRL** - Glare rating **Ra** - Colour rendering			

Table 1 - EN12464-1 schedule of illuminance and recommendations related to hospitals and healthcare buildings

Uniformities and the relationship between illuminance in areas immediately surrounding task areas are shown in Table 2:

Illuminance on the task area (lx)	Illuminance on immediate surrounding areas (lx)
>750	500
500	300
300	20
200	150
150	E task
100	E task
<50	E task

Table 2 - Illuminance of area surrounding the task area (Source: CIBSE LG2)

2.3. Emergency Lighting

An important part of any lighting scheme is emergency lighting as it ensures the safe evacuation, movement or continuation of a medical procedure in the event of a power failure.
Emergency lighting can be categorized as follows (as indicated in BS5266-1: Emergency lighting - Code of practice for electrical low mounted way guidance systems for emergency use):

- Emergency escape lighting: total immediate evacuation
- Emergency safety lighting: allows occupants to remain within the premises
- Standby lighting: allows normal activities to continue
- The main requirements for these areas are as follows (as per BS5266-1):

    - Escape routes: the horizontal illuminance on the floor along the center line of an escape route up to 2 m in width should not be less than 1 lux.

- Open areas: rooms with a floor area greater than 60 m2, or those having been risk assessed as needing emergency lighting, should be provided with horizontal illuminance of not less than 0.5 lux at the floor level of the area, excluding a border of 0.5 m around the perimeter. For areas less than 60 m2, consultation will be required to identify areas where emergency lighting may be needed; examples are given in BS 5266-1 (BSI, 2016).
- High risk task areas: if emergency escape lighting is required to provide illumination for the safety of people involved in a potentially dangerous process or situation, and to enable proper shut-down procedures for the safety of the operator and other occupants, the illuminance value should not be less than 10% of the average of the normal lighting at the location of the point of the risk.

2.4. Light Sources

The type of light source selected is very important. All areas should use light sources with high color rendering properties, i.e., an R value >80. In areas where the detailed activities are known, it is important that the spectral distribution of the light source used is aligned with the requirements of the task, to ensure no distortion of colors even if a high R value is achieved (which is possible with LEDs). In addition to the color rendering, all light sources in the same area for the same purpose should be of the same color temperature, this will also help with future maintenance. A big component of the healing experience is achieving a high level of patient comfort which is why indirect or integrated architectural lighting is also encouraged to avoid the harsh effect created by direct downlighting.

2.5. Comfort and aesthetics

2.5.1. Stakeholders Comfort

Hospital lighting design should incorporate features that will infuse the comfort, calmness and healing. The overall patient, staff and caregiver experience is deemed important. Patients experience uncertainty and vulnerability when admitted to a healthcare facility as they have the feeling of not being in control. The ability to control lighting empowers them and restores some sense of power. Furthermore, lighting techniques used should enhance the experience such as, rooms with non-uniform lighting brightness on at least one wall support the perception of pleasantness and relaxation. Staff comfort affects turnover rates, effectiveness, behavior and indirectly benefits patient care quality.

Visitors will often be the primary caregivers when the patient leaves the hospital. Continuation of care after the hospital is vital and the visitor presence in a comfortable environment will extend the time of their presence and hence increase the opportunity of the staff conveying information and training on the patient care.

2.5.2. Priority lighting needs

In a healthcare facility, the needs of occupants and functional operations are conflicting in most of the times. For example, darkness supports restorative sleep, but medical staff require illumination to complete their tasks. The lighting system should consider both needs. Designers should be mindful when selecting luminaires where the patient's primary view is the ceiling by considering brightness and glare. In most cases, task ambient solutions that use a controllable light is a common method to accommodate all needs.

Another concern within healthcare lighting systems is lighting trespass defined as the lighting entering a patient's room from corridors and nursing stations when the patient is resting or sleeping. Photometric lighting distribution for luminaires are important and influences the selection. Another example of conflicting needs is the nursing station that needs to remain alert however, also needs to limit light exposure to protect circadian rhythms.

2.5.3. Glare control

Hospitals often use hard glossy surfaces for different furniture or work elements. This type of surface often reflect glare that is as irritating as direct glare. The selection of luminaires should take into account the photometric properties of the luminaire and the angles at which light will be striking different surfaces and affecting the users (patients, staff, visitors).

2.5.4. Aesthetics

Designing lighting systems in a healthcare facility to create an attractive environment with cues for navigation and destination points improves the comfort of the users. To create importance, the luminous exitance (amount of light leaving a point on a surface) of a surface should be twice that of the adjacent surfaces and no more than 5 times the surrounding illuminance levels to avoid creating a focal point that detracts visual acuity.

Illuminating walls or ceilings makes a room seem more spacious and pools of light define task areas. Reduced illuminance levels create a mood of intimacy.

The demographic of patients should be taken into consideration. An older population needs a higher light level with limited excessive brightness while pediatric patients need fun distractions to put them at ease.

3. Typical Lighting Arrangements

In the following section, different lighting needs for different sections of a healthcare facility are presented. These recommendations are be used in conjunction with the EN12464-1 (schedule of illuminance and recommendations related to hospitals and healthcare buildings – Figure 8) and the Illuminance of area surrounding the task area table previously presented (Figure 9).

3.1. Entrance Areas

Aside from patients, people visiting healthcare facilities will spend most of their time within the common areas while waiting for news or procedures. These common areas should have a calm and relaxing feel. Lighting can play an essential role in this purpose. The proper lighting levels and uniformity will ensure the visitor's comfort. Consideration should be given to the inclusion of accent or feature lighting to enhance the visual quality of the space. A healthcare facility's entrance may include other functional areas such as a reception, a cafeteria, information screens and waiting areas. This means that the lighting design should account for additional / various elements to make visitors and patients feel in a less clinical and relaxed space (CIBSE, 2019). Tables 3 and 4 shows the illuminance requirements for entrance halls, waiting areas, reception and enquiry desk and Figures 12 and 13 show typical hospital lighting entrance and waiting area design.

Location	Maintained illuminance (lux)	Notes
Floor	200	The lighting while being functional should mirror the efficiency and drama created at the reception areas of major commercial buildings. The lighting calculations should not focus solely on delivering 200 lux uniformly over the floor but should also identify small specific areas where the lighting level needs to be brighter or dimmer to satisfy functional or visual needs.

Table 3 - Entrance halls and Waiting area illuminance requirements (Source: CIBSE LG2)

Location	Maintained illuminance (lux)	Notes
Reception (floor)	300	A measure of retail lighting philosophy should be employed to create a welcoming and impressionable ambience.
Enquiry desk (task area)	500	Comfortable accent lighting techniques should be employed to make the desk visually stand out from the general surroundings. Vertical Illuminance: ensure suitable illuminance on the faces of the staff and visitors on both sides of the reception and enquiry desks. Daytime/night-time: consider the function of each reception or enquiry desk throughout the day and reduce the illuminance or provide a more relaxed ambience during the evening and night time.

Table 4 - Reception and enquiry desk illuminance requirements (Source: CIBSE LG2)

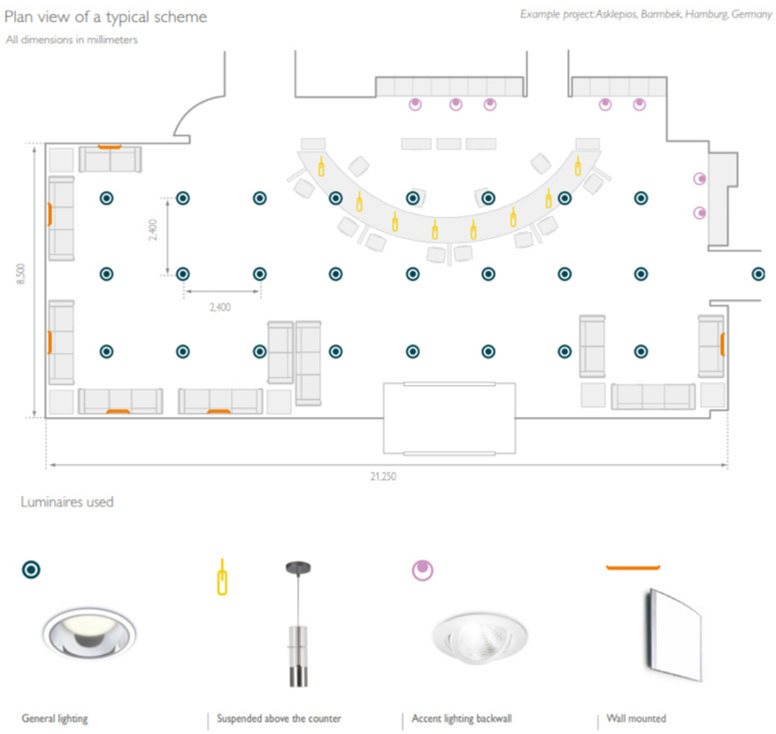


Figure 9 - Typical Entrance lighting Design (Source: Philips)

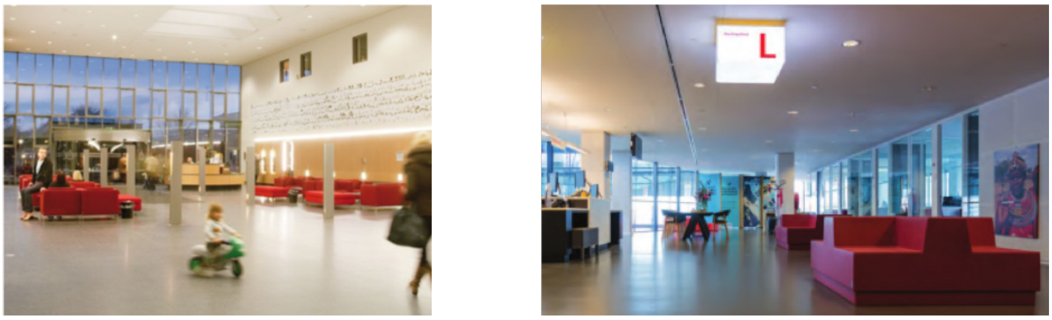


Figure 10 - Examples of Hospital Entrance and waiting Areas (Source: IES and CIBSE)

3.2. Corridors and circulation

Corridors and circulation areas are the arteries of the facility, logistically linking different sections together. These areas are considered transitional and usually do not require the same level of design considerations as the remaining functional areas of a hospital. Corridors and circulation areas are considered one of the most energy consuming sections of a healthcare facility. The lighting in these spaces should not impact trolley-borne patients or deliver nuisance light into the wards.

Signs (direction / informative) shouldn't be masked from view by shadows or glare. Furthermore, when positioning lighting fixtures in corridors, care should be given to lighting trespass. Finally, using wall mounted luminaires or applying lighting designs that work with natural light, gives the opportunity of providing light to both ceilings and wall surfaces. Corridors and circulation areas can be classified as hospitality areas and medical areas. Table 5 summarizes Circulation and corridors Illuminance requirements.
Hospitality areas being the space where patients often meet each other and talk while walking while medical areas are spaces between or leading to specific medical sections such as operating theatres, radiology section, or other functional areas. Lighting design approach for these two types can be different as shown in figures 11 and 12:

Location	Maintained illuminance (lux)	Notes
Circulation (floor)	200 (day) 50 (night)	Uniform illumination levels should be provided to avoid bright and dark patches to walls and floors. The installation should also be capable of operating at a reduced level (50 lux with 0.4 uniformity) at night for comfort and energy efficiency. Avoid the setting out of lights such that they cause nuisance levels of brightness into corridors in the evening.
Corridors (floor)	150	Uniform illumination levels using low glare luminaires positioned to avoid alternating brightness patterns being viewed by trolley-borne patients. The installation should also be capable of operating at a reduced level (50 lux with 0.4 uniformity) at night for comfort and energy efficiency.
Stairs (landings and treads)		150 lux on landings/half landings and the first step from each landing or half landing; 100 lux on all other steps. Consider access for maintenance and avoid wall luminaires that expose the lamps when ascending or descending the stairs.

Table 5 - Circulation and corridors Illuminance requirements (Source: CIBSE LG2)

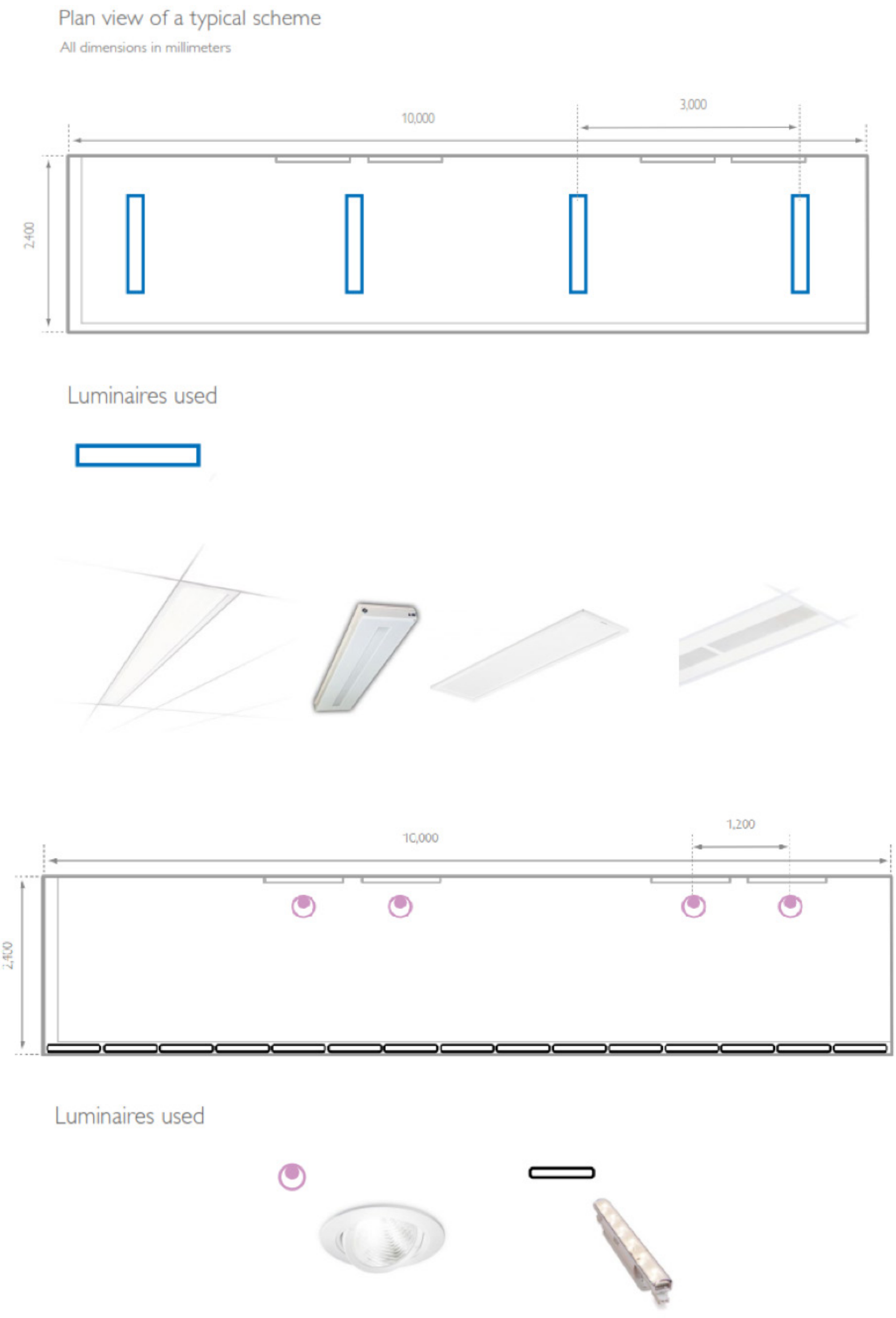


Figure 11- Typical Hospitality Corridor Lighting Design (Source: Philips)

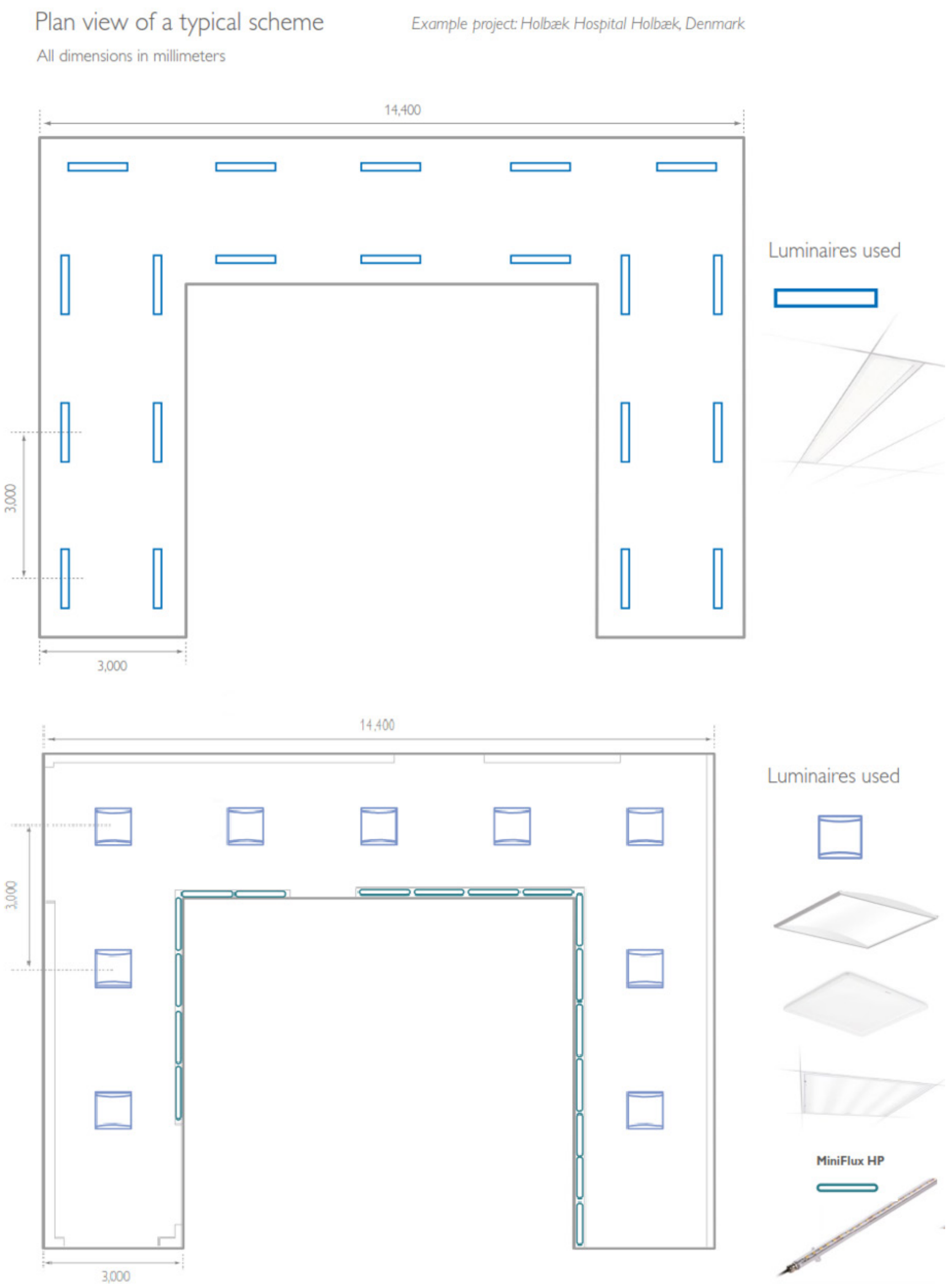


Figure 12 - Typical Medical Corridor Lighting Design (Source: Philips)

3.3. Examination rooms

Examination rooms are an essential part of patient care. Reduced light level eases discomfort and intimidation. However, increasing illumination is needed for performing examination and minor procedures. A combination of ambient and task illumination may be layered to achieve these goals. Examination rooms should be equipped with medical examination task lights. Luminaires within the line of sight of the patient should be visually comfortable (see Figure 13). Color rendering is also an important consideration. A minimum CRI of 80 is considered sufficient (IES, 2020). Variable lighting levels may be achieved by using multi-level switching allowing a lower illuminance level to be set until the caregiver is ready to perform the examination. Table 6 shows the examination rooms illuminance requirements.

Location	Maintained illuminance (lux)	Notes
Working plane	500	Luminaire selection and positioning is important to avoid visual discomfort to patients.
Couch or chair (local)	15,000 to 30,000	To be provided by a local examination luminaire.

Table 6 - Examination rooms Illuminance requirements (Source: CIBSE LG2)

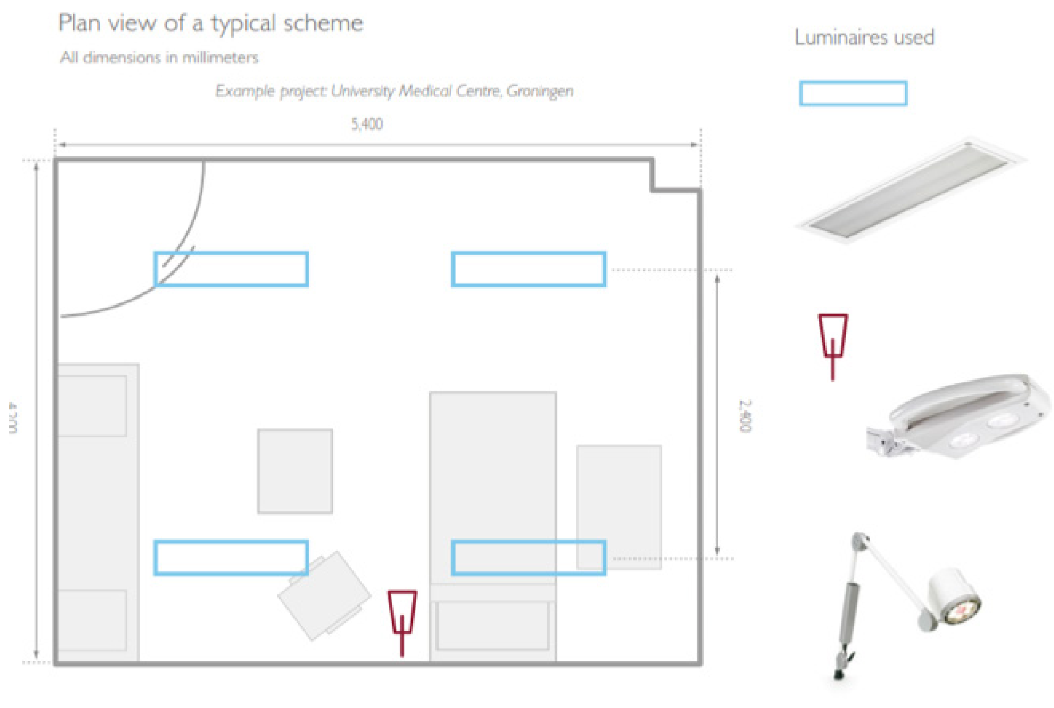


Figure 13 - Typical Examination Room Lighting Design (Source: Philips)

3.4. Diagnostic imaging (MRI/CT scanning/PET/ultrasound/X-ray)

Imaging rooms incorporate a range of facilities like x-ray imaging, fluoroscopy, ultrasound, MRI, pet scan, and others. General lighting needed for these areas is for entry and patient transfer for initial setup. Emphasis should be made on creating a stress free and calm environment. Luminaires should be controlled at the room entrance and the control desk. Ceiling mounted fixtures should consider the movement of the imaging machine (see Figure 14). Radiation lights are also required outside the room. Table 7 shows the imaging rooms illumination requirements.

Location	Maintained illuminance (lux)	Notes
Trolley and equipment	500	Luminaire selection and positioning is important to avoid visual discomfort to patients.

Table 7 - imaging rooms illuminance requirements (Source: CIBSE LG2)

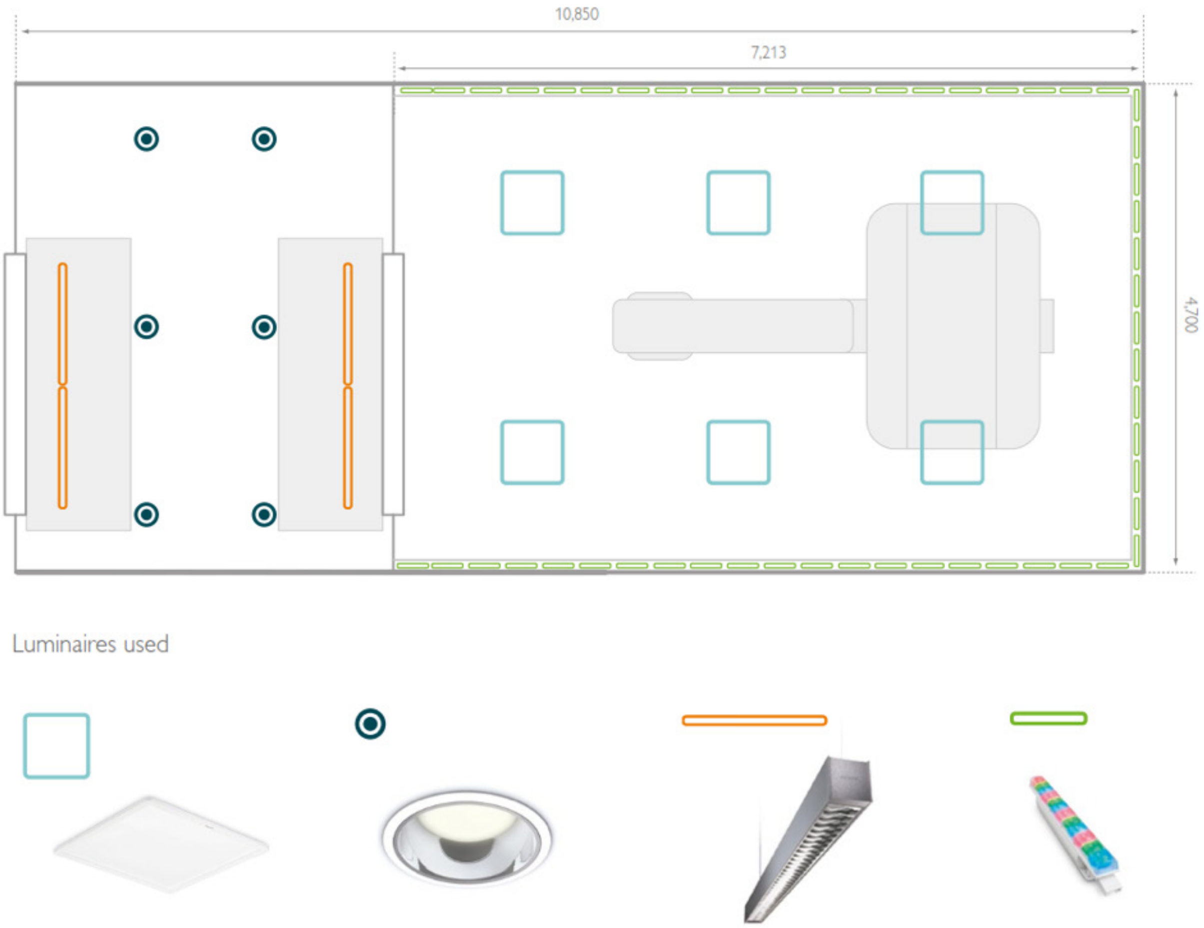


Figure 14 - Typical Imaging Room Lighting Design (Source: Philips)

3.5. Patient Rooms

Patient room lighting design should make it appear less institutional while fulfilling needed task lighting requirements. Limiting the amount of light occurring during the night is essential hence the importance of providing nightlights within rooms to allow for proper observation (Figures 15 & 16). In case of a multi patient room, the privacy of each patient must be considered. There are three zones typically in a patient room: the patient zone, the caregiver zone, and the family zone. Lighting system design should address all available tasks/zones. Specific considerations for patient room design include the following:

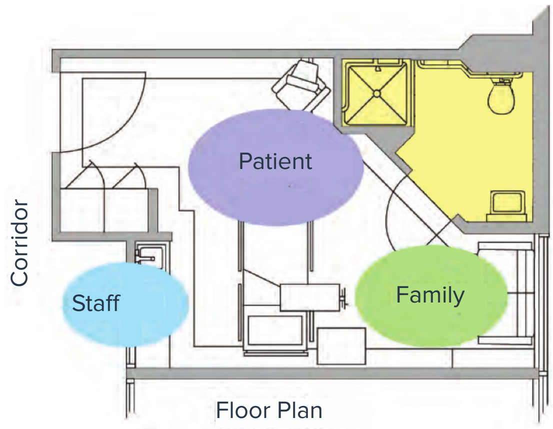


Figure 15 - Typical Patient room zones (Source: IES)

- Ensuring proper luminaire cover
- Position luminaires in such a way to avoid veiling reflections on televisions or handheld devices
- Lighting control should be at the entrance and the patient proximity
- Exam illumination to be provided by downlights and independently switched from the headwall
- The family zone should have independent control
- Patient control of window shades should be considered

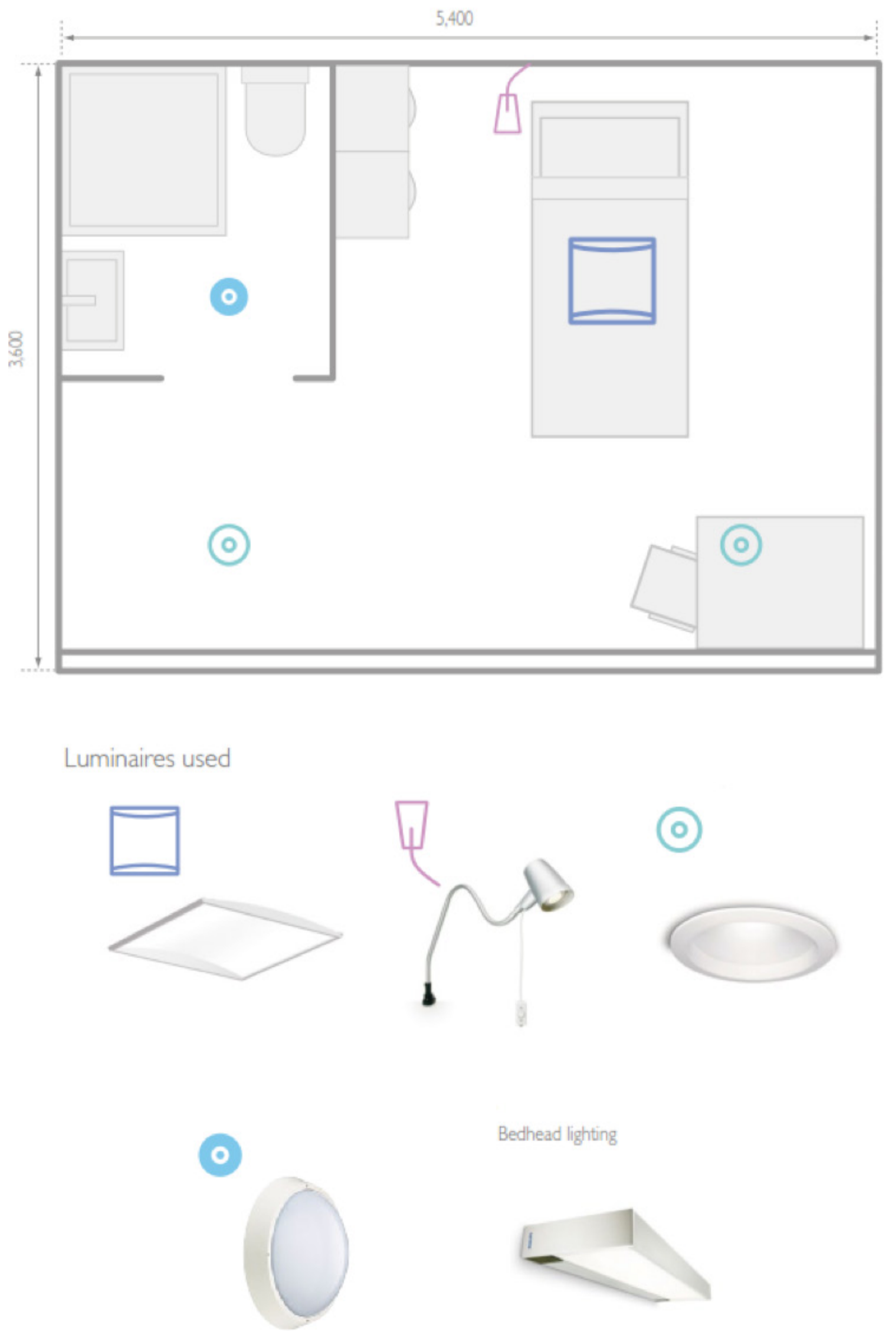


Figure 16 - Typical Patient Room Lighting layout (Source: Philips)

3.6. Nurse Stations

These areas area usually sited away from windows with a view or access to daylight. Maintained illuminance should be 300 lux during the day and between 30 to 200 lux at night. The higher value is used for exacting visual tasks such as dispensing medicines. Dimming will also allow the staff to adjust the amount of light to suit the night-time tasks (CIBSE, 2019). Near the floor, shielded lighting should be provided on the front of the base (nurse) station for nighttime use when normal lighting is off which will allow the edge of the base station to be seen by patients and staff moving around. Table 8 shows the nurse station illuminance requirements.

Location	Maintained illuminance (lux)	Notes
Desk (day and evening)	300	Low glare luminaires suitable for use with visual display terminals should be used to provide operator comfort and avoid any visual distraction to patients.
Night-time	30–200	This can be provided by selected switching or dimming of the main luminaires, or using a suitable desk lamp.

Table 8 - Nurse stations Illuminance requirements (Source: CIBSE LG2)

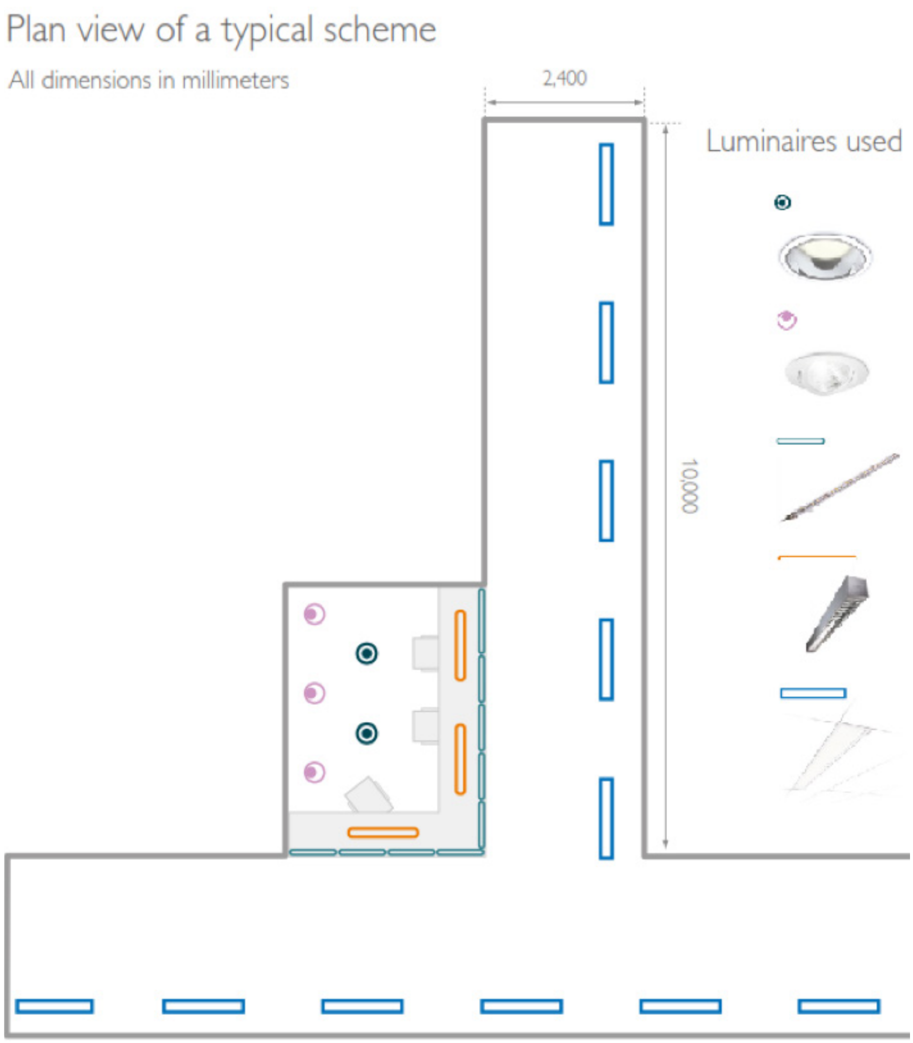


Figure 17 - Typical Nurse Station Layout

3.7. Operating Theatres

The type of surgical procedure that is to be performed determines the needed level of illumination and angle of illumination. In addition to the surgical light, it is necessary to select an operating luminaire that will provide the best solution. The general lighting requirement is 1000 lux and is adequate to perform ancillary tasks by the staff. This is the level that should be provided across the whole room and not just the central bed area. Luminaires in this area should be specifically designed for similar areas and should have a dual ingress protection (IP) rating of IP65/54 (see Figure 18). The first rating is for the side facing the room and the second rating is for the luminaire side facing the ceiling. The luminaire should be designed for easy cleaning and the material used in the construction of the luminaire should not be affected by the repetitive use of cleaning chemicals (see Table 9).

Location	Maintained illuminance (lux)	Notes
Operating table (directed locally)	10,000 to 160,000	Local switching
Operating theatre (general lighting)	1,000	Dimming
All other places where work is carried out	≥ 500 but ≤1000	Dimming

Table 9 - Operating Theatre Illuminance requirements (Source: CIBSE LG2)

Figure 18 - Typical Operating theatre Lighting Layout (Source: Whitecroft lighting)

3.8. Technical Rooms:

Like most facilities, healthcare facilities require technical areas for building services equipment. These areas require proper illumination for the maintenance staff to be able to perform their duties properly. Often neglected, these areas have poor lighting quality and are not on the priority list when it comes to maintenance or repairs. Most of the time, technical rooms end up with partly operating lighting systems. Table 10 can be used for illumination levels of different areas.

Table 10 - Technical Areas Recommended Lighting Level (Source: CIBSE)

Area	Lighting Level
Switchboards	300 Lux
Boiler house	100 Lux
Control rooms	300 Lux
Mechanical plant rooms	150 Lux
Electrical plant rooms	100 Lux

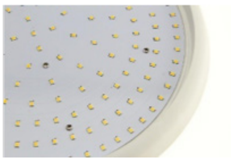
4.
LED Lighting Specifications

The benefits of LED lighting are achieved through proper selection of luminaires. Performance of LED luminaires vary dramatically from one manufacturer to another. Technical data should first be checked and understood before installation.

- **Types of LED:**

Standard through-hole LED: often used as indicator light source, although with low light output. Due to their shorter service life, higher probability of failure and sensitivity to UV radiation, they are not used in lighting technology.

SMD (surface mounted device) LED: a LED that is reflow-soldered to the surface of a printed circuit board (using a reflow oven). Basically, it consists of an LED chip protected by silicon coating mounted in or on a housing or a ceramic plate with contacts.



CoB (chip on board) LED: the LED chip is mounted directly on the printed circuit board. This allows a dense arrangement of chips close to each other.

- **LED features**

The choice for LED lighting is validated by the following features:

- High efficiency = high luminous efficacy (lumen/watt)
- Long service life
- Broad spectrum of white light (warm white to daylight white)
- No UV or infrared radiation
- Compact size
- Good to excellent color rendering index (R)
- Luminous flux and service life highly temperature-sensitive
- No environmentally harmful materials (e.g. mercury)
- Resistant to vibrations and impact Saturated colors
- Immediate start, i.e. 100 % luminous flux after switching on
- No ignition, boosting or cooling time
- High-precision digital dimming
- No shifting of color locations during dimming
- Luminous flux & service life greatly dependent on temperature (increase at lower temperatures)

The key performance quality documents and testing methods in relation to led luminaires:

- IEC 62717: LED modules for general lighting — Performance requirements (IEC, 2014/2015/2019)
- IEC62722-2-1: Luminaire performance — Part 2-1: Particular requirements for LED luminaires (IEC, 2014)
- ANSI/IESNA LM-80-15: Approved Method: Measuring luminous flux and color maintenance of LED packages, arrays & modules (IESNA, 2015)
- IESNA TM-21-11: Projecting Long Term Lumen Maintenance of LED Light Sources (IESNA, 2011)
- Luminaires intended for use within clinical areas of healthcare buildings should specifically comply with the requirements of BS EN 60598-2-25 (BSI, 1995).
- Luminaires accessible to patients should either be of Class II construction or supplied from safe extra-low voltage (SELV) supply, as defined in BS EN 60598-1 (BSI, 2015).

Verification of compliance against these standards should be sought from the luminaire manufacturers.

IEC/PAS documents suggest the following list of quality criteria to be considered when evaluating manufacturer’s claims:

- **Rated input power:** The rated input power shows the amount of energy consumed by a luminaire, including its power supply. It is expressed in watts (W).
- **Rated luminous flux:** It corresponds to the light emitted by the luminaire (unit of light output) which is expressed in lumen (lm).
- **LED luminaire efficacy:** the measured initial luminous flux divided by the measured initial input power of the same individual LED luminaire. It is expressed in lumens per watt (lm/W).
- **Luminous intensity distribution:** The spatial distribution of the luminous flux graphically depicted in a luminous intensity distribution curve, which is usually expressed in a polar coordinate diagram representing the light intensity as a function of angle about a light source. It is expressed in candela (cd).
- **Photometric code:** A six-digit photometric code that displays the important ‘quality of light’ parameters: CRI, CCT, chromaticity co-ordinates and luminous flux.
- **Rated Color Rendering Index (CRI):** The color rendering of an LED module giving white light is the effect on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant and it is unitless.
- **Correlated Color Temperature (CCT):** The color temperature of a LED module giving white light is determined by comparing the light emitted by the LED module with light of an ideal black-body radiator at the given temperature. It is expressed in Kelvin (K).
- **Rated chromaticity co-ordinate values:** Both initial and maintained. The behavior of the chromaticity co-ordinates of a LED module expressed in two measurement results of both initial and maintained chromaticity co-ordinates.
- **Lumen maintenance code:** The measured initial luminous flux (initial value) is normalized to 100% and used as the first data point for determining the LED module life. The maintained luminous flux (maintained value) is measured at 25% of rated lifetime up to a maximum of 6,000 hours and expressed as percentage of the initial value. The maintained value determines the lumen maintenance code.

- **Failure fraction (Fy):** corresponding to the rated life of the LED module in the luminaire. The percentage (y) of a number of LED modules of the same type at their rated life designates the percentage (fraction) of failures. This failure fraction expresses the combined effect of all components of a module including mechanical, as far as the light output is concerned. The effect of the LED could either be less light than claimed or no light at all.

- **Ambient temperature (tq) for a luminaire:** The ambient temperature around the luminaire related to the specified performance. For a given performance claim the ambient temperature (tq) is a fixed value. It is possible to specify performance claims at different ambient temperatures. It is expressed in degrees Celsius (°C).

- **Rated life of the LED module and the associated rated lumen maintenance (lux):** The length of time during which a population of LED modules provides more than the claimed percentage (x) of the initial luminous flux always published in combination with the failure fraction. It is expressed in hours (hr). Figure 19 displays curves for different LED fixtures showing the relative light output percentage drop as service life increases.

- **Service life data for LEDs:** the service life describes the time until the mean light output of an LED luminaire has dropped to a specified percentage of the initial light output.

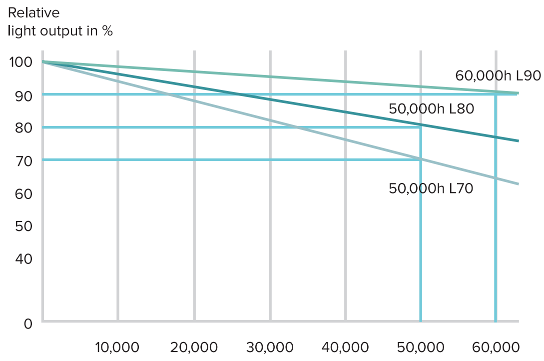


Figure 19 - different LED fixtures relative output curves

5. Lighting Control

The benefits of installing a lighting control system include the improvement of patient care tasks, increased energy efficiency and reduced operating costs. Lighting control varies in complexity from manual control of individual fixtures to programmed scenes and networked systems interfaced with BMS systems. Where applicable, automated controls are preferred over manual switches to avoid the need to clean additional surfaces while disinfecting. Automation should not be capable to interfere with proper care delivery.

Automated controls have become widely used. Exceptions to the use of controls are placed when safety could be compromised. Different technologies exist for automated controls and once a technology is selected, setpoints of the devices should be selected and validated after installation.

- Occupancy sensors and vacancy sensors (Figure 20): time delay, sensitivity and occupancy logic should be set.
- Photosensors (Figure 21): dead band response time, target-maintained illuminance.
- Timed switches (Figure 22): duration for which lights are kept on

Areas like corridors use timed controls to incorporate nighttime illuminance levels hence the need of an override switch for nursing staff to restore full illumination on emergencies. Patients' ability to control lighting in their rooms and treatment areas allows them to feel a sense of control and comfort. In some case, lighting control is integrated within a controller that is able to operate the television, nurse call, and curtains.

Staff control: lighting switches for staff should be located in specific locations identified from staff operation / presence in the area in question. Table 11 identified recommended control types per area usage.

Area	Control Type
Public areas / waiting rooms	daylight harvesting time scheduling
Labs and pharmacies	occupancy sensors / motion sensors
Examination and treatment	manual scene control
Surgical areas	scene setting and remote access
Nursing stations	day/night light level control
Corridors	day/night light level control
Patient rooms	task appropriate light levels

Table 11 - Control type per area (Source: OSRAM)

Figure 20 - Occupancy sensor

Figure 21 - PIR sensor

Figure 22 - Timed switch

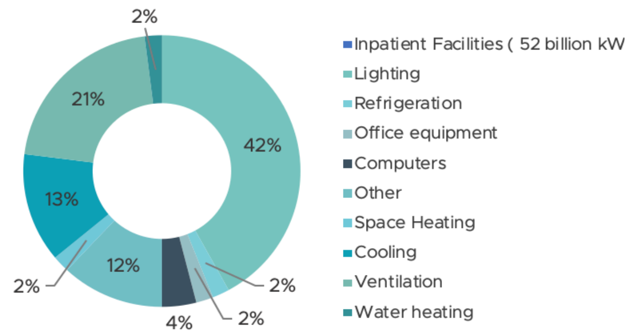
6.
Energy Efficiency in Healthcare

A healthcare facility is often the largest consumer of energy and environmental resources in a specific area and the burden being put on these facilities to become increasingly sustainable is great. Sustainability has become tightly related to energy savings and in the current energy and power crisis faced in Lebanon and around the world, achieving energy saving goals is essential. However, energy savings cannot be at the expense of functionality of the facility.

6.1. Lighting Efficiency

When it comes to lighting, it is important to consider maintenance procedures, upgrade opportunities and how to address future failures. Healthcare facilities usually have a very high energy use intensity (US Department of Energy) as they operate 24/7 with HVAC and energy intensive medical equipment in addition to laundry and other support areas. Lighting in hospitals could represent up to 40% (Figure 23) of the electricity consumed (IES, 2020)

Inpatient Facilities (52 billion kWh)



Outpatient Facilities (20 billion kWh)

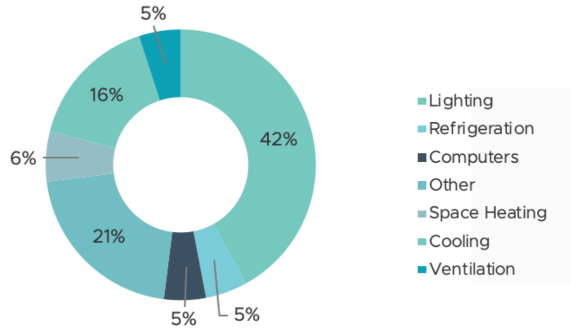


Figure 23 - Energy Use in Healthcare facilities (Source: US DOE, 2003)

6.2. Daylighting

Figure 24 - Daylight from skylights for the waiting area (Source: EwingCole Architects)

Daylighting is the harnessing of the light entering through windows, skylights, and other means through the building. Leveraging the use of daylighting creates a more pleasant environment, reinforces circadian entrainment for the people inside the facility in addition to ensuring energy savings. Making use of daylighting requires a coordination between the lighting designer and the architects, interior designers or facility managers. In case of new construction, the orientation of the building can be in such a way to maximize exposure to daylight while minimizing direct view of the sun (see Figure 24).

Artificial lighting improves many aspects of daily life however, the consumed power creates hazardous byproducts and greenhouse gas emissions which provide a strong incentive to opt for energy efficient systems. Lighting systems can also contain hazardous material in the waste stream when manufactured or disposed of and create light trespass to neighbors or wildlife. Taking all these issues into consideration when designing or redesigning a lighting system is a good practice to create a more sustainable future (IES, 2020).

6.3. Economics

When investigating the economic benefit from a lighting redesign or retrofit project, it is essential to understand the difference between initial investment cost and operating cost. The goals of the projects may differ, for example, a redesign or a retrofit for a short term leased space will put more emphasis on the initial investment rather than the operational costs that are more considerable for a long-term approach. Operating costs are also related to the product life cycle assessment and performance. Lighting energy saving and maintenance costs have an important consideration in the total cost of the project. Assessing savings from a certain lighting project should be over the course of the expected lifetime.

6.3.1. Hard vs Soft Cost

Operational costs can be divided into hard and soft costs. Hard costs are quantifiable and can be included in the budget such as energy consumption cost and supplies. Soft costs on the other hand are as important as hard costs but difficult to measure. These include the effect on improved patient care, shortened length of stay, lower cost per patient, higher turnover dur to increase in patient capacity, personnel retainment, and reinforced brand image.

6.3.2. Cost Savings

The return on investment of LEDs is highly situational and analysis should be performed using realistic values specific to each situation and facility. Some lighting companies have developed spreadsheets with payback calculations, which are useful, but only when the values and comparisons are appropriate for the situation. There are many factors to be considered when determining whether to make an investment for LED lighting. These include the initial cost of the fixtures, the lifetime of the fixture, the efficiency, the electricity rate and the hours of operation.

Cost saving depends on the lighting upgrade option that was chosen. Figure 25 gives an idea about possible energy saving depending in the selected lighting upgrade approach. It shows the cost increase and expected energy savings depending on the retrofit approach that is selected, whether lamp replacement, luminaire replacement, or a complete lighting redesign.

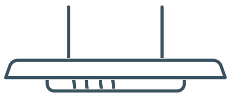
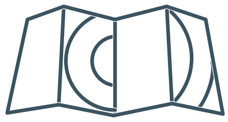
Retrofit Approach			
Description	 **Lamp replacement** Lamps, bulbs, and tubes are replaced with more efficient versions in existing luminaires.	 **Luminaires replacement** Luminaires, or fittings, refer to the whole fitting, including the lamp and the control gear housed inside it. Full luminaires are replaced on a like for like basis with more efficient version	 **Lighting redesign** A new lighting designs is developed according to current best practice.
Cost	Low	Medium	Medium to High
Typical energy savings	50% or more	60-75% or more	70% or more
Considerations	Ballast and controls need to be considered. Does not tackle existing design deciencies	Does not tackle existing design deciencies. Need to asses if lighting levels will remain acceptable	Cost very dependent on ancillary costs, e.g. ceiling repairs.

Figure 25 - Lighting Upgrade options and potential savings (Source: SEAI)

7.
Disposal of Lamps and Lighting Fixtures

A lighting retrofit project will generate a large amount of waste. The main components of old lighting fixtures that should be properly disposed of are:

- Lamps
- Ballasts
- Luminaire casing

All fluorescent lamps and tubes are considered hazardous when they are discarded because they contain mercury. This includes:

- Fluorescent lamps, tubes and ballasts.
- Fluorescent tubes, including low mercury tubes.
- Compact fluorescents, including low mercury lamps.
- High Intensity Discharge (HID) Lamps and ballasts:
- Metal halide lamps, such as floodlights for large indoor and outdoor areas and gymnasiums.
- Sodium lamps, such as those sometimes used as security lighting and outdoor floodlights.
- Mercury vapor lamps, such as those sometimes used for street lighting.

All fluorescent lamps, tubes and ballasts must be recycled, or taken to a hazardous waste disposal facility, a universal waste handler, or an authorized recycling facility. Fluorescent lamps, tubes and ballasts should be packaged carefully when storing and transporting them and to be stored away from rain so that if they break, the mercury from broken lamps or tubes will not be washed by rainwater into waterways.

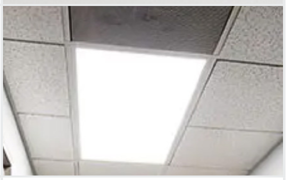
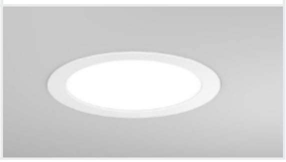
8.

Case study – Lebanese Public Hospitals LED Retrofit

As part of the Solar for Health (S4H) project funded by KfW, UNDP performed a lighting audit for 15 public hospitals (see Figure 26). The selected hospitals played a major role in treating patients during the COVID19 pandemic. The audit led to a lighting retrofit project aiming to deploy energy efficient LED lighting systems that would improve the lighting fixtures' lifetime, reduce energy consumption and total harmonic distortion, respect task matching lighting color, increase light loss factor and improve lamp lumen depreciation factor. Special attention was placed on the technical specifications for the lighting requirements for all internal areas of the hospitals.

Figure 26 - Map of interventions under the KfW-funded UNDP S4H project

The Solar for Health Project retrofitted lighting in several hospitals, replacing existing fixture with more efficient ones, as outlined in Table 12.

Old Fixture/Lamp		New Fixture/Lamp	
Lamp/Fixture Type	**Picture**	**Lamp Fixture**	**Picture**
Incandescent bulb		12 watts LED E27 Bulb	
60 cm / 120 cm / 150 cm Fluorescent T8 Tubes With or without ballasts		60 cm / 120 cm / 150 cm LED T8 replacement Tube	
60x60 cm 4 x 18 watts fluorescent T8 Tubes Recessed mounted lighting fixture		60x60cm LED Recessed mounted Panel	
60x60 cm 4 x 18 watts fluorescent T8 Tubes Surface mounted lighting fixture		60x60cm LED surface mounted Panel	
120x30 cm 2 x 36 watts fluorescent T8 Tubes recessed mounted lighting fixture		120x30cm LED Recessed mounted Panel	
120x30 cm 2 x 36 watts fluorescent T8 Tubes Surface mounted lighting fixture		120x30cm LED Surface mounted Panel	
60x60 cm 4x18 watts fluorescent T8 clean room rated		60x60 cm LED panels clean room rated	
120x60 cm 4x36 watts fluorescent T8 Tubes recessed mounted lighting fixture		60x120cm LED Recessed mounted Panel	
2x36 watts fluorescent T8 lighting fixture for technical areas		Surface Mounted LED IP54 120 cm Fixtures (30watts)	
2x26watts CFL recessed fixture		Recessed mounted round LED panels	

2x26watts CFL surface mounted fixture		Surface mounted round LED panels 18 watts	
50 watts halogen spot		Recessed mounted round LED panels 5 watts	
		Recessed mounted round LED panels	

Table 12 - Solar for Health Lighting Retrofit Interventions

Below are some pictures from the existing conditions at the hospitals (see Figures 27 to 30):

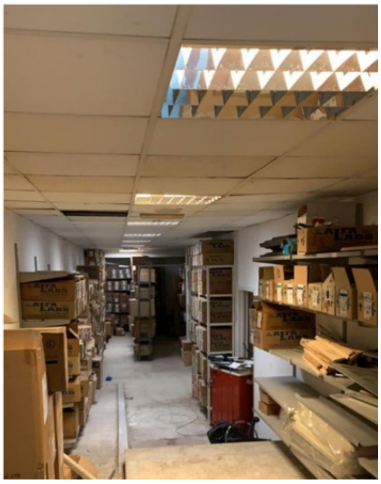


Figure 27 - Lighting system condition in Tripoli Public Hospital

Figure 28 - Lighting System Condition in Hermel Public Hospital

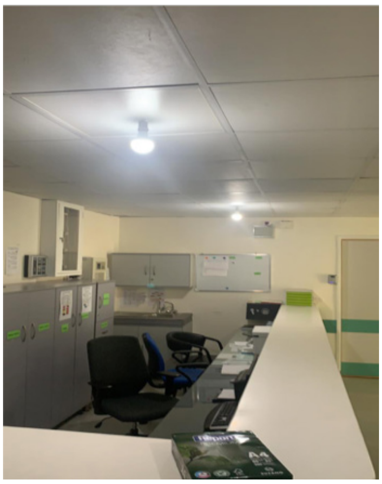


Figure 29 - Lighting System Condition in Nabatiyeh Public Hospital

Figure 30 - Lighting System Condition in Bint Jbeil Public Hospital

Summary of baseload findings per hospital are shown in Table 13, along with the possible yearly savings achievable with efficient lighting retrofits.

Hospital	Lamp/lighting fixtures to be replaced	Connected total load reduction (W)	Estimated Yearly (kWh) reduction per hospital
Bcharre	132	1,779	7,792
Halba	402	10,660	46,691
Tripoli	4.425	64,046	280,521
Baalbak	1,299	22,656	99,233
Mashghara	1,890	29,864	130,804
Bint Jbeil	4,691	54,836	240,182
Nabatiyeh	1,570	44,037	192,882
Hermel	1,456	42,128	184,521
Keserwan	288	3,522	15,426
RHUH	10,398	254,977	1,116,799
Daher Al Bachek	921	29,830	130,655
Sahar Al Gharbe	1,206	29,638	129,814
Total	28,678	587,973	2,575,320

Table 13 - Summary of LED retrofit interventions impact per hospital

*The connected total load reduction is calculated for the total number of fixtures per hospital multiplied by the total load reduction in W. The estimated yearly reduction in kWh is calculated on an average of 12 hours of daily connected load reduction in KW and for 365 days.

Going into details for one particular hospital, the Rafic Hariri University Hospital (RHUH), Table 14 indicates the detailed intervention on lighting undertaken by the Solar for Health Project.

Fixture reference	Lamp/ Fixture Type	RHUH Main Building	RHUH Auxiliary buildings	Complete RHUH Campus	Old fixture/ lamp wattage (W)	Peak Watts reduction per replaced lamp/ fixture (W)	Total Peak Load Reduction (W)	Total Yearly Reduction (kWh)
Type B	8 watts 60 Cm LED T8 replacement Tube	1,554	692	2,246	18	10	22,460	98,375
Type C	14 watts 120 Cm LED T8 replacement tube	3,080	246	3,326	36	22	73,172	320,493
Type D	24 watts 150 cm LED T8 replacement tube	709	0	709	58	34	24,106	105,584
Type E	60x60cm 41 watts LED Flush mounted Panel	2,005	502	2,507	72	31	77,717	340,400
Type F	60x60cm 41 watts LED surface mounted Panel	80	20	100	72	31	3,100	13,578
Type G	120x30cm 41 watts LED Flush mounted Panel	0	22	22	72	31	682	2,987
Type H	120x30cm 41 watts LED Surface mounted Panel	112	244	356	72	31	11,036	48,338
Type M	Surface Mounted LED IP54 120 cm Fixtures (30watts)	439	88	527	72	42	22,134	96,947

Type O	Flush mounted round LED panels 18 watts	0	347	347	52	34	11,798	51,675
Type P	Surface mounted round LED panels 18 watts	0	258	258	52	34	8,772	38,421
Total number of fixtures		7,979	2,419	10,398			Total yearly kWh Reduction	1,116,799
Total estimated budget (USD)		239,452	91,035	330,487				

Table 14 - RHUH detailed Lamps/Fixtures replacement impact summary

*The total peak load reduction in W is calculated as the total number of replaced lamps/fixtures multiplied by the peak watts reduction per lamp/fixture. The total yearly reduction in kWh is calculated on an average of 12 hours of total peak load reduction in W and for 365 days

As indicated in Table 14, for RHUH alone, approximately 1,117 MWh of electricity is saved per year through lighting retrofits. This saving corresponds to an annual cost saving between $163,800 - $391,000 (depending on cost of electricity, the range herein corresponding to between $c14 - $c35 per kWh). The simple payback period of the lighting retrofit in RHUH corresponds to a range between 10 months and 2 years, similarly depending on the price of electricity.

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