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Quality indoor lighting for comfort, health, wellbeing and productivity

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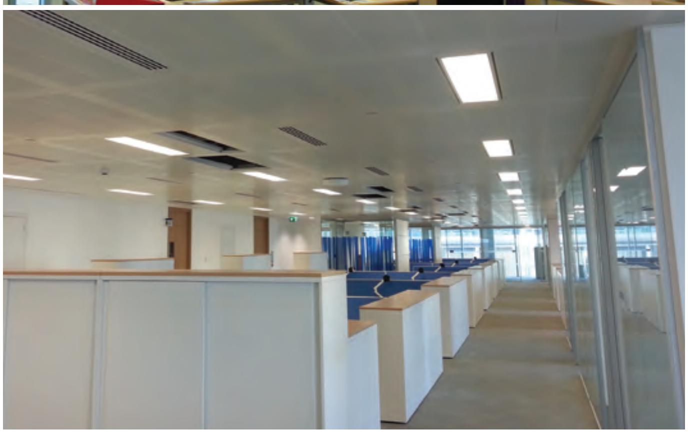

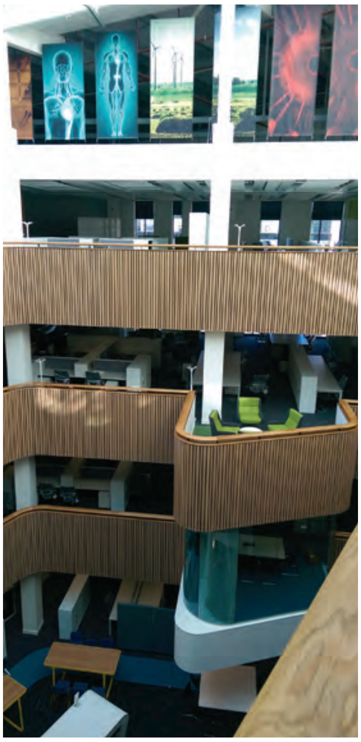

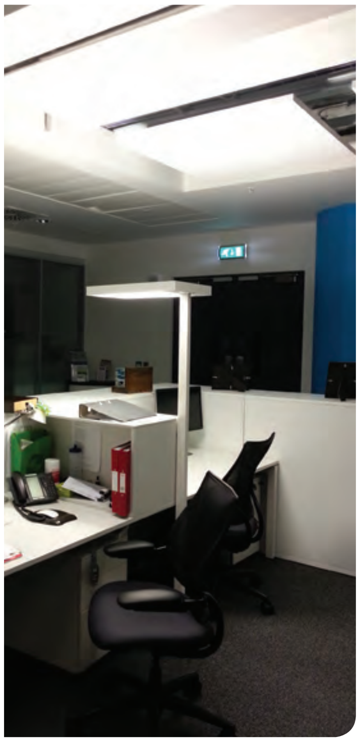

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Introduction

Suitable indoor lighting and lighting controls are not only essential for people to work and move around a building safely, but also play a key role in their comfort, wellbeing, health and productivity.

Poor lighting can cause visual discomfort which may result in sore eyes, headaches, and the aches and pains associated with poor body posture. Well designed lighting can not only prevent these problems, but also help to maintain a healthy physiological and psychological balance through its influences on hormone secretions, body temperature, cognitive activities and moods.

Building designers, owners and occupants need to be aware of the potential benefits of careful lighting design that meets the recommendations of codes and standards, and ensures that occupants' visual requirements are met. These recommendations address lighting design issues such as the type of activity in the building, health, visual comfort and performance, individual requirements and emergency lighting.

In practice, indoor lighting is not always designed or installed to standard recommendations, and this can adversely affect occupant wellbeing, comfort, health and productivity. Where problems occur, specialist post-occupancy evaluation of artificial lighting is recommended. This involves expert visual assessment of the installed lighting, coupled with specific lighting measurements and computer modelling of the luminous environment. It can identify the causes of the problems and recommend improvements tailored to the specific needs of the occupants and the building.

Lower level ambient lighting scheme in an open plan office, before the addition of task lighting. Building designers and managers need to be aware of the benefits of careful lighting design – and the risks associated with poor design

The role and impact of indoor lighting

The role of indoor artificial lighting is to provide adequate visual conditions for human activities to be carried out efficiently and comfortably, and to enable people to move safely around a building.

Good lighting can result in greater productivity and concentration during the day, and better sleep at night, particularly for elderly people and those confined indoors. Poor lighting can make it hard to see clearly and may contribute to slips, trips or falls, whilst too much bright light can cause dazzle and mask otherwise obvious hazards. Insufficient light, high light contrasts, glare, shadows and flicker, can all make visual tasks difficult. These difficulties lead in turn to visual discomfort in the form of red, itchy eyes, headaches, and aches and pains associated with poor body posture (SLL, 2009).

Lighting and comfort

Among the key aspects of indoor lighting that influence the comfort of the people in a lit space are glare, flicker and lighting controls

Glare
Human eyes can adapt to a wide range of light levels from almost total darkness to very bright scenes, but only a limited range of light levels will be comfortable. Too much light or excessive differences in brightness can lead to glare. Bright light sources can cause disability glare, which can lead to safety problems because it stops people seeing a task properly.

The most common form of glare, discomfort glare, occurs when elements of an interior are much brighter than others. It can lead to visual discomfort and fatigue, eyestrain, headaches and postural problems without affecting the ability to see; it can also adversely affect mood and wellbeing.

Bright light reflected from specular surfaces in the field of view can cause reflected glare. Images of light sources on reflective screens or glossy paper can make task details difficult to see and can cause visual discomfort. Projectors directed at wall-mounted vertical whiteboards can also cause specular reflection from the whiteboard, visible as a glare spot that is bright enough to cause discomfort or even disability glare (Winterbottom and Wilkins, 2009). Polished floors have also been found to be a common source of glare for people with visual impairments in healthcare buildings (Huisman et al, 2012).

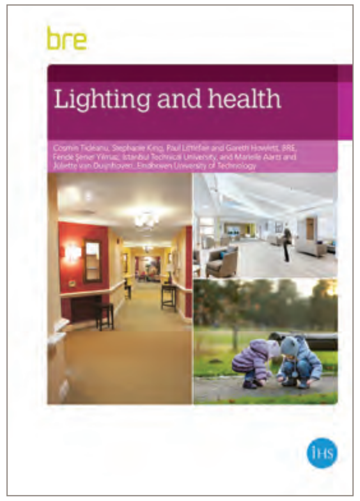
Flicker
Human eyes are particularly sensitive to flicker, a rapid and repeated change in the brightness of light. Flicker is seen mainly towards the edges of the visual field. Although various factors influence it, generally people can detect flicker at frequencies of 60 Hz and lower (Bullough et al, 2011). Below 60 Hz, flicker can cause visual discomfort, fatigue, decreased visual performance, headaches and eyestrain, or even photosensitive epileptic seizures in those who are susceptible (Wilkins, 1994; Wilkins et al, 2010).

Above 60 Hz, flicker is generally too rapid to be visually perceived by most people. However, some studies have found that even at frequencies well above 60 Hz flicker, although unseen, may have effects on visual performance (Veitch and McColl, 1993), and long-term exposure to such unseen flicker may lead to potential health problems such as headaches and eyestrain (IEEE, 2010). Lamps operating at very high frequencies, such as most fluorescent lamps with electronic ballast, are much less likely to cause problems with flicker.

Controls
Lighting controls enable a space to be suitably lit for the safety and comfort of users. They need to operate in a way that is appropriate to the type of space and needs or expectation of the users (Littlefair, 2014). Inadequate controls can lead to physical injuries due to poor illumination, for example, from tripping or falling in an unlit space.

They may also frustrate users who cannot control their environment effectively, especially in a space where it would traditionally be expected. For example, if occupancy sensors are not positioned correctly and do not turn on or off as expected, people will soon become irritated. These factors can add to stress. Where users do have some form of individual control, issues may arise from a lack of training or inappropriate control interfaces. Not understanding how to use the control leads to confusion, errors and frustration. Training and user knowledge of the system is an often overlooked aspect of design (King et al, 2014).

Lighting and health



Lighting has the potential to affect the general health of people in buildings (Ticleanu et al, 2015). This goes beyond the safety aspects of providing enough illumination to see by, and avoiding glare and flicker. Light also helps maintain a healthy physiological and psychological balance through its effects on hormone secretions, body temperature, cognitive activities and moods.

Lighting can alter our body clocks. Recently scientists have found a sensor in the eye that sends signals to the brain to control the hormones that make us alert or sleepy. Exposure to bright light resets the body clock. This is one of the health benefits of daytime lighting, and seems to have a positive effect on mood and avoiding depression. Conversely, too much light at night can disrupt sleep and cause health problems.

The effects depend on the amount of light and its spectrum, as well as its dynamic changes over the course of a day. Therefore, lighting must meet complex human needs: emotions, moods, actions, perceptions and health are all influenced by light. Daylight appears to have particular benefits as it can provide variability and contact with the outside as well as high levels of light, improving mood.

Standard recommendations and guidance on indoor lighting

Guidance on indoor artificial lighting is given in BS EN 12464-1 Light and lighting – Lighting of work places. Part 1: Indoor work places (BSI, 2011), BS EN 1838-2013 Lighting applications – Emergency lighting (BSI, 2013) and BS 5266-1:2016 Emergency lighting – Part 1: Code of practice for the emergency lighting of premises (BSI, 2016), as well as in the SLL Code for Lighting (SLL, 2012) and the SLL Lighting Handbook (SLL, 2018).

Recommendations for specific types of building or application are given in additional SLL Lighting Guides (e.g. for offices, industry spaces, hospitals and health care buildings, museums, communal residential buildings etc.), and other documents such as BRE's guide to retail lighting (Ticleanu et al, 2013) and BRE Digest 498 Selecting lighting controls (Littlefair, 2014).

The various lighting guidance documents deal with lighting design, aspects of health, visual comfort and performance, as well as individual requirements based on the type of activity undertaken, and emergency lighting.

Illuminance

Lighting standards and codes use maintained illuminance as the main criterion for the amount of light. It is the value below which the average illuminance (measured in lux) on the specified surface is not allowed to fall. The recommended values for maintained illuminances in various indoor spaces are given for normal visual conditions, and can be increased or decreased when visual conditions differ from normal.

Although patterns of light and shadow can make a space look more appealing and animated, excessive variations over the visual field can lead to discomfort. Lighting standards and codes recommend minimum uniformity levels in most space types, particularly task areas within workplaces, to ensure visual performance and visual comfort. BS EN 12464-1 (BSI, 2011) and the SLL Code for Lighting (SLL, 2012) differentiate between task area, immediate surrounding area and background area. In general, the task can be brighter than its immediate surroundings, which in turn can be brighter than the background, but the contrast should not be too great.

Standards usually recommend maintained illuminances on a horizontal plane or on task surfaces. Face recognition is important in many spaces, and people often judge the brightness of a space by the light on vertical surfaces. In such cases, standards also recommend cylindrical illuminances and/or ratios of cylindrical illuminance to horizontal illuminance. Cylindrical illuminance at a point (also measured in lux) is the average illuminance falling on the curved surface of a vertical cylinder located at the specified point (it does not include light falling onto the ends of the cylinder). It is therefore a good measure of the light falling on someone's face.

Lighting standards give recommendations for maintained illuminances on working planes or task surfaces

Luminance distribution

Visual comfort and visual performance are affected by the distribution of luminance (or brightness) in the field of view. Too high luminances may cause glare, and too high luminance contrasts will cause fatigue because the eye has to constantly re-adapt. However, too low luminances and too low luminance contrasts result in a dull and non-stimulating environment. So, it is important to create a well-balanced luminance distribution in the lit space. Luminance depends on the illuminance on the surfaces and their reflectances.

Bright interior surfaces, particularly walls and ceiling, are recommended for the visual comfort of occupants. BS EN 12464-1 (BSI, 2011) and the SLL Code for Lighting (SLL, 2012) give recommended ranges of reflectances for the major interior surfaces, and also recommend walls and ceiling illuminances for enclosed spaces.

Glare

Disability glare from artificial lighting can be avoided by the correct aiming of light towards areas of interest, as well as by shielding lamps and bright parts of luminaires against direct view. Minimum shielding angles are given for luminaires depending on lamp luminance (SLL, 2012).

Discomfort glare in interior lighting is quantified by the Unified Glare Rating (UGR). This index calculates the total glare effect of the light sources in relation to background luminance as seen from the observer's eye. Maximum UGR limits are given by standards (BSI, 2011; SLL, 2012) for different types of space and for various applications. A lower UGR value should give a more comfortable luminous environment.

Glare can be a particular problem for computer users. Additional recommendations are provided to limit luminaire luminance for work places using display screen equipment. Reflected glare can be limited by correctly arranging visual display units with respect to luminaires and other bright light sources; by using matt surfaces rather than glossy finishes; by restricting the luminance of luminaires and other light sources; and by using high reflectance finishes for ceilings and walls to brighten up the space (BSI, 2011; SLL, 2012). Uplighting strategies reduce the risk of glare for occupied spaces.

Colour

In general, standards and codes recommend a warmer light colour appearance for buildings located in zones with colder climate conditions in order to create a pleasant indoor atmosphere, especially in domestic spaces.

Correct, natural rendition of colours of objects in the environment is also essential for visual performance, comfort and wellbeing. The colour rendering index (CRI) indicates how good a lamp is at rendering colours. Lighting standards (BSI, 2011; SLL, 2012) recommend minimum values of CRI for different types of interior, task or activity so that people can recognise coloured objects. The higher the CRI, the better the light source renders a wide range of colours in the visible spectrum, with a CRI of 100 being considered ideal.

Bright light sources can cause disability glare, which can be avoided by correctly aiming or shielding the lamps

The contrasts provided by the energy efficient lighting system in this new shop gives the space a vivid and dynamic appearance, which will enhance the presentation of the merchandise

Flicker

Most conventional electric light sources supplied at mains or similar frequencies can exhibit flicker due to regular fluctuations in the Alternating Current (AC) supply. These include the older type of mains frequency fluorescent lamps. LED lamps can also flicker, especially when they are retrofitted into the building and used with existing lighting controls. AC LEDs are more susceptible to output variations due to power surges and voltage fluctuations.

In general, flicker can be minimised by ensuring supply stability or by using high-frequency electronic control gear. LED drivers of acceptable quality employ high-frequency power supplies that attenuate the AC component of the mains supply at the output and thus help reduce flicker. Flicker can still occur when dimming LED lamps with mains voltage dimmers and drivers. Direct Current (DC)-based LED drivers are available that can dim the light output of the LED lamps to less than 1% whilst avoiding the risk of flicker (IET, 2014).

Lighting controls

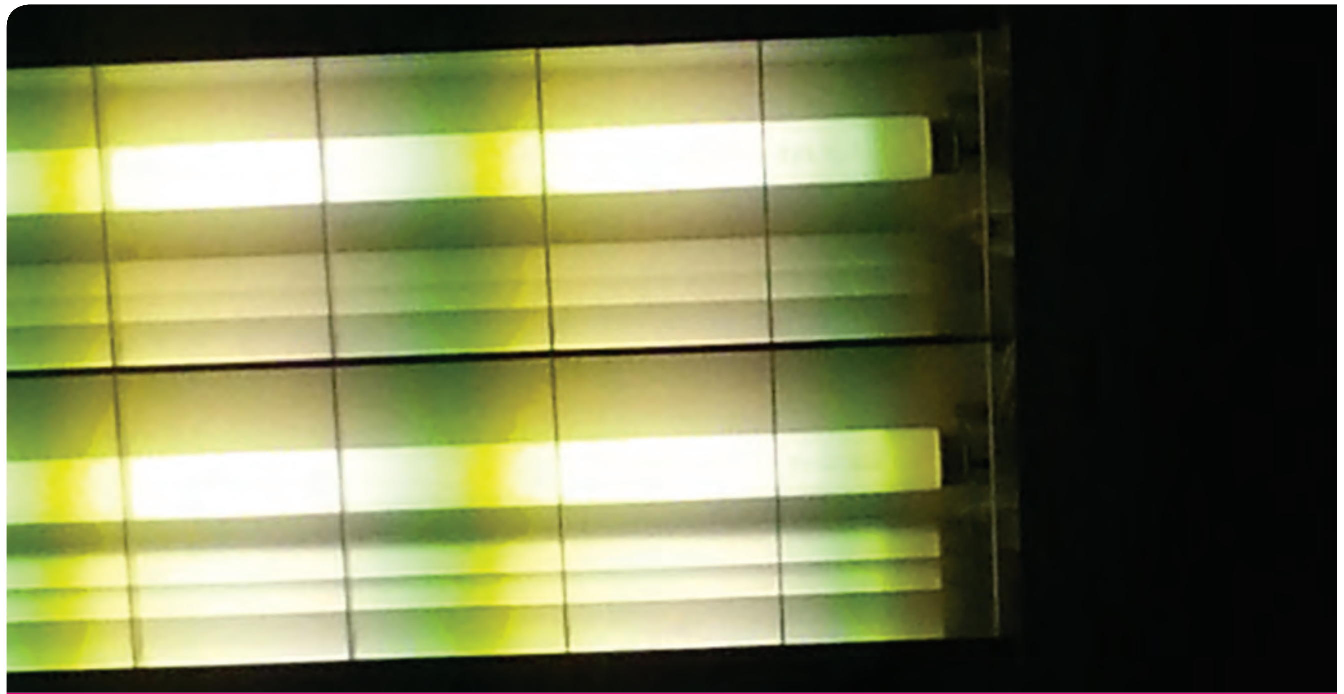
Having control over the lighting of a space is important for the safety its users, and lighting controls should be designed with the space and needs and expectations of users in mind. Therefore, the type of control used must suit the type of space and the visual needs of the users of that space (Littlefair, 2014).

People differ in their expectations of the level of control they should have, depending on the kind of space involved. A BRE Information Paper on lighting controls discusses the concept of ownership of a space (Slater et al, 1996). For example, in owned or shared spaces such as offices or meeting rooms, users would expect to have at least some control over the lighting. In unowned or managed spaces such as corridors or entrance halls, users would not expect to have control over the lighting, but would expect them to be adequately lit when they move through these spaces.

It is equally important to ensure that users are familiar with the lighting controls installed in the space they occupy, and that they know how to use them. Often the simplest solution is the best (King et al, 2014).

Emergency lighting

Most buildings need emergency lighting for safe evacuation or safe continuation of essential processes. When the normal lighting fails, emergency lighting must be activated for as long as potential hazards exist, or until normal lighting is resumed. Standby lighting enables activities to continue safely, whilst escape lighting enables people to leave a space safely. Different forms of emergency lighting have different purposes: escape route lighting, open area (anti-panic) lighting, high risk task area lighting, standby lighting and signage lighting. Various requirements apply to each form of emergency lighting (BSI, 2013; BSI, 2016; SLL, 2015).



Most conventional electric light sources using low frequency control gear can exhibit flicker, a rapid and repeated change in brightness

Energy efficiency

Energy efficient lighting is recommended by various standards and codes. However, reducing lighting energy consumption should not affect the luminous performance of the lighting system. Minimum illuminance values should still be maintained to meet standard recommendations. BS EN 12464-1 (BSI, 2011) recommends various measures to reduce energy use for lighting inside buildings. These include harvesting daylight; responding to occupancy patterns; improving maintenance of the lighting system; and using appropriate lighting controls. It is important not to over-specify light levels, and to use efficient lighting systems.

Building Regulations Part L 'Conservation of fuel and power' sets standards for the energy performance of new and existing buildings. The Non-Domestic Building Services Compliance Guide (HM Government, 2014) indicates minimum values of luminous efficacy for lighting. The luminous efficacy is the ratio of light output to consumed power, expressed in lumens per Watt. There is an alternative option in the form of a lighting energy limit, the Lighting Energy Numeric Indicator (LENI, expressed in kWh/m2/year), which can take into account daylight-based switching or dimming and occupancy sensing. Maximum LENI values are recommended for different hours of use and maintained illuminances.

EU Green Public Procurement encourages public authorities to procure environmentally friendly products and services, including indoor lighting. The scheme includes criteria for energy efficient lighting systems such as, for example, maximum values for lighting power density, expressed in W/m2, and normalized lighting power density, expressed in W/m2/100lux, for different types of space and application.

The lights are on in this office despite the abundant natural light. It is important to integrate lighting controls with daylight availability, so that artificial lighting is dimmed or switched off when there is sufficient daylighting

Post-occupancy evaluation of indoor lighting problems

In practice, indoor lighting is not always designed or installed to standard recommendations, and this may affect occupant comfort, health, wellbeing and productivity. For example, occupants may experience glare from lighting that is too bright, visual discomfort from an unbalanced distribution of light, or flicker from luminaires that are faulty or old enough to be using low frequency control gear. All of these can in turn result in sore eyes, headaches, and aches and pains associated with poor body posture.

Where problems occur, BRE can undertake specialist post-occupancy evaluation of artificial lighting and recommend improvements. This is based on expert visual assessment of the installed lighting coupled with specific lighting measurements and computer modelling. The typical evaluation protocol covers the amount of light (illuminances), uniformity and distribution of light, the sequential experience of lighting in different spaces, the colour of light and room surfaces, glare, flicker and potential problems using display screen equipment.

Case study – Office space

Problem
As part of a lighting upgrade plan, the ceiling recessed fluorescent luminaires installed in an open-plan office were replaced with ceiling recessed LED panels on a one-by-one basis. However, occupants reported the newly installed LED panels to be too bright and glaring. They were keeping some of the new panels switched off to try to reduce visual disturbance.

Solution
BRE carried out a site visit to investigate the lighting scheme and its impacts on space occupants. This included specialist measurements of surface reflectances, wall and ceiling illuminances, luminaire luminances and desk illuminance. Additional computer modelling was performed to assess glare in the space from the newly installed LED lighting. Staff members were informally interviewed about the lighting and whether they had experienced glare.

The lighting scheme directed nearly all of the light downwards to illuminate the floor and work surfaces. The staff felt that too much light was coming from above. Additionally, in direct lighting schemes with ceiling-recessed luminaires, the luminaires tend to be very bright, and the ceiling and/or the walls look relatively dark. However, with the entire lighting system switched on, the average illuminance on the walls and the ceiling was in line with guideline recommendations to achieve a good balance of brightness in the space.

The newly installed ceiling recessed LED panels in this open-plan office were reported to be too bright and glaring by the people working here

The average desk illuminance measured in the office space with all the lighting switched on was below the standard recommendation. Nevertheless, staff members perceived the lighting as being too bright and often switched off some of the new luminaires. Then the average illuminance on work areas decreased by 46% and the resulting illuminance was significantly below the recommended value. Also this did not reduce discomfort glare because the contrast between luminaires and background was similar. Computer modelling showed that the number of desk positions with a glare (UGR) index above the recommendation actually increased from two to three.

As a solution, BRE recommended a number of options in order to balance the luminance distribution in the office space:

- Install dimming facilities so that light levels can be dimmed to suit staff needs.
- Change lighting control groups so that the lighting in different zones can be controlled independently of each other. Maintain separate controls for luminaire rows.
- Provide additional light on walls by using extra luminaires along the perimeter of the office space.
- Provide task lighting in the form of desk lights to enable individual staff members to set the light level on their desk as required.

A more complex, alternative solution would involve replacing the existing lighting with dimmable direct-indirect lighting, as well as providing controls and task lighting.

Case study – Secondary school

Problem
A post-occupancy environmental monitoring of indoor conditions, including lighting, within the school building was requested as a part of a larger project on the quality of internal environments in UK healthcare and education.

Solution
BRE evaluated the lighting conditions in various spaces in the school building.

All areas assessed were lit by ceiling-recessed lighting using either T8 fluorescent lamps with magnetic ballasts, or compact fluorescent lamps (CFL) with high frequency electronic ballasts. The T8 luminaires had direct, downward light distribution, and the CFL ones were fitted with direct-indirect optics. The lighting was controlled by a combination of wall-mounted switches or dimmers and occupancy sensors in some parts of the building, and by fully manual on/off switches in others. There were classrooms in which lighting was not dimmable, although these were fitted with projection equipment. Dimming is recommended by BS EN 12464-1 (BSI, 2011) in spaces with screen projection.

The average illuminance in classrooms was well above the recommended 300 lux for teaching spaces in BS EN 12464-1, ranging from 36% to 49% above the recommended value. Illuminance uniformity met standard recommendations.

In other areas, such as the staff room and reception, the average illuminance, was 51% to 88% above the recommended. Illuminance uniformity met standard recommendations. In general, the recommendations in the SLL Code for Lighting (SLL, 2012) for wall illuminance relative to working plane illuminance were met.

The colour rendering index CRI appeared to be above 80, thus meeting the BS EN 12464-1 recommendations. However, some of the lamps in one classroom were of an old type with a colour rendering index CRI between 50 and 59. Therefore the recommendation was to replace these lamps with newer fluorescent tubes, which have a colour rendering index above 80.

Although the lighting in most areas visited did not appear glaring, glare was reported in one of the classrooms that may have caused visual fatigue and occasional headaches to students. Excessive luminaire luminances were recorded, and additional computer modelling showed that the UGR (glare) value was above the recommended maximum in most of the classroom. Therefore the recommendation was to replace the existing luminaires with low luminance ones or with indirect luminaires suspended below the ceiling.

BRE evaluated lighting conditions in areas of a school lit by two types of ceiling recessed fluorescent luminaires

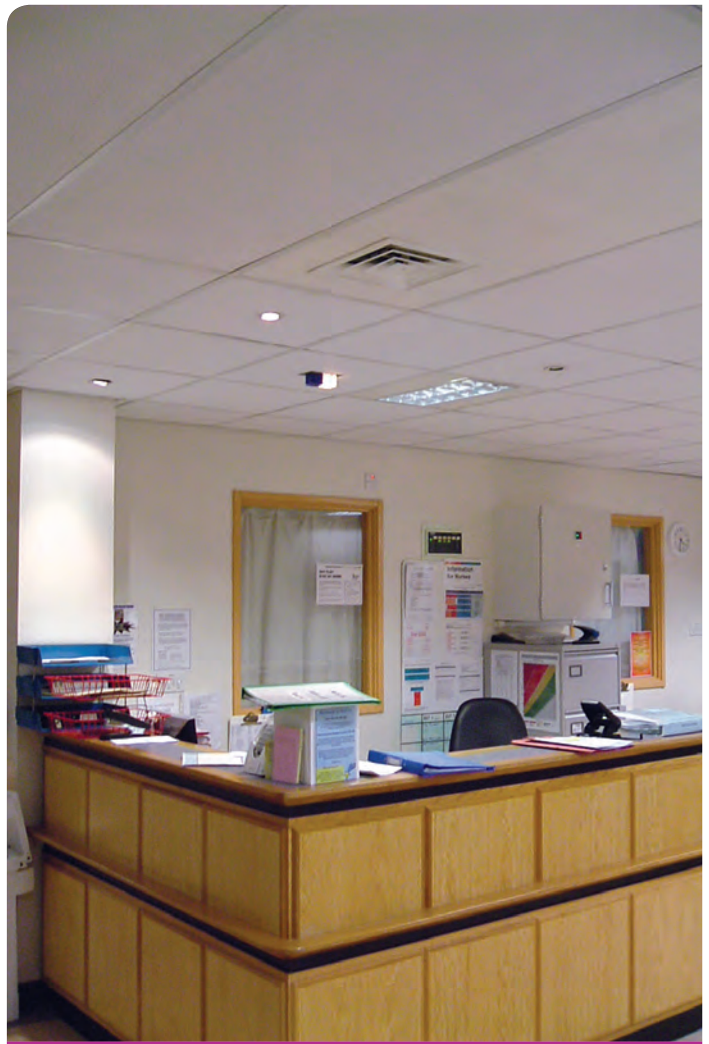
Case study – Hospital

Problem
The hospital management requested expert advice and consultancy for improving the lighting inside the hospital building whilst reducing its energy consumption.

Solution
The existing lighting systems have been assessed and measured by BRE in various areas across the hospital. Illuminances on specific task surfaces were measured and compared with the recommended levels. One area was found where the lighting was inadequate and illuminances were well below standard recommendations. Relighting, or extra lighting was recommended for this area.

There was more scope for improvement in reducing lighting energy consumption and maintenance costs. The most urgent issue was to replace pearl tungsten bulbs used in bedhead reading lights with dimmable LED lamps, giving an average energy saving of 83%. There was very little automatic control of the lighting, which meant that a lot of lighting was left on during the night when spaces were unoccupied, or during the day when daylight levels were sufficient. In a few places lighting had been switched off to save energy, but in one lift lobby this meant that lighting was inadequate at night. Some of the corridors were over-lit, and energy could be saved by turning off alternate fittings.

Lighting was assessed across the hospital, including here, where ceiling lights in an asymmetric lighting system direct light onto walls



Illuminances on specific task surfaces were measured and compared with the recommended levels

Recommendations were made to improve lighting controls. These included using photoelectric control linked to daylight sensors in daylit areas, with an average energy saving of 33%, and using occupancy sensing in unoccupied spaces including consulting rooms, staff offices, seminar rooms, utility rooms and lesser used corridors, giving an average energy saving from 25% to 33%.

To meet the Trust's 10% overall energy saving target, replacement of at least 20% of the hospital's existing lighting was also recommended. Potential measures included replacing halogen spotlights with LED downlights, with an average energy saving of 80%, and replacing T8 fluorescent luminaires with highly efficient luminaires using T5 fluorescent or LED lamps and high frequency electronic control gear, which would have led to an average energy saving of at least 50%.

Case study – University campus

Problem
The occupants of university offices were due to relocate to a new, larger building. Post occupancy evaluation compared the lighting in the existing buildings, before the staff relocation, with the new open plan environments after relocation.

Solution
BRE carried out an expert visual assessment of the electric lighting in both sets of spaces, with measurements of illuminances, luminance and reflectance. Questionnaires found staff views of the quality of the indoor environments and identified specific areas of concern.

All the rooms assessed within the existing buildings were lit by fluorescent lighting, which appeared to be generally well maintained, except for some failed and flickering lamps in one of the buildings. Fully manual on/off switches were used to control the lighting in all rooms assessed, with no dimming or daylight linking facilities. Occupants were not satisfied with the lighting controls and wanted more flexibility in setting their own light levels.

The average illuminance on the working plane from electric lighting was below standard recommendations in most of the areas assessed. However, the occupants of one office area considered the lighting to be too bright and uncomfortable, and preferred to switch off the ceiling mounted lighting and use two floor standing uplighters instead.

Surface reflectances and the colour of electric lighting in the existing buildings were generally within standard recommendations. The lighting did not appear glaring in any way and no reflected glare could be noted on display screens.

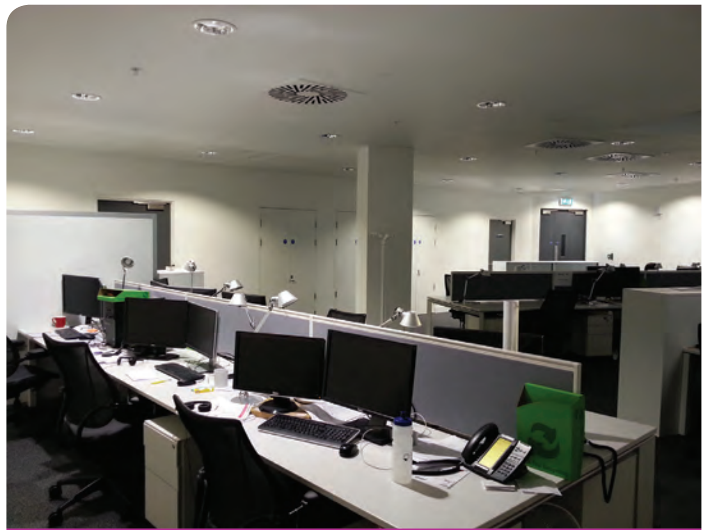
All the locations assessed in the new building were lit by fluorescent or LED general lighting, with additional LED task lighting in open-plan areas. General lighting in all areas was automatically controlled by presence detection. Luminaires by the windows in the open-plan areas were automatically dimmed in response to daylight, although some of them appeared to dim incorrectly. No manual controls were provided in any of the open-plan areas and cellular offices. The occupants wanted manual override control over the lighting in their work area, but manual switching was only available for desk lights.

The average desk illuminance in the open-plan areas was below the 500 lux recommended for offices in BS EN 12464-1 (BSI, 2011), even if task lighting was added to general lighting. In cellular offices, it was just below the 500 lux recommendation. Using desk lights led to worse illuminance uniformity.

Prior to the relocation of university office staff from the above location, lighting in this and the new location was assessed and compared

Surface reflectances and the colour of electric lighting in the new building were generally within standard recommendations. The fluorescent luminaires did not appear glaring in any way, and no reflected glare from these luminaires could be noted on display screens. Nevertheless, the LED downlights used in some open-plan areas were too bright and occupants either turned some of them off or placed vertical panels to protect themselves against glare.

Overall, the occupants of the open-plan areas assessed in the new building viewed the general electric lighting as poor, and the new offices appeared to be lit to lower levels than their previous offices. BRE recommended that controls are revisited where applicable to ensure that the settings in all control groups are similar, and that additional local lighting is provided in order to increase the illuminance and improve the illuminance uniformity on the desks. Options could include floor standing luminaires with a wide light distribution.



Assessment of lighting in the new location enabled potential problems to be identified, and recommendations made to deal with them

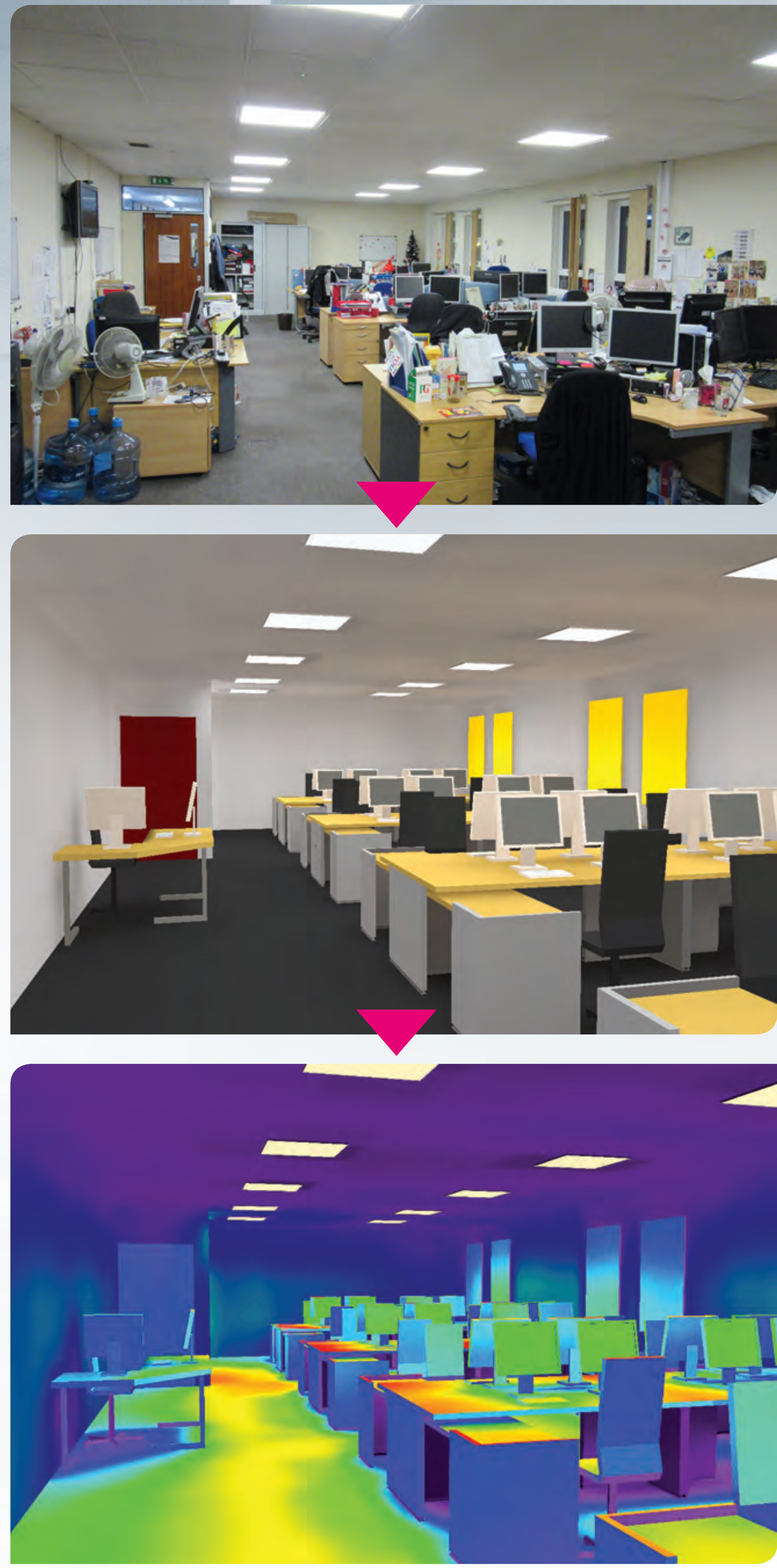
Conclusion

The quality of the indoor environment is crucial as it can affect occupants' health, wellbeing, comfort and productivity. Adequate artificial lighting and lighting controls, including the provision of emergency lighting, are essential to enable people to work and move around a building safely.

Lighting can also affect the health of people in buildings. Poor lighting, particularly if it causes glare, can give visual discomfort which may result in sore eyes, headaches, and aches and pains associated with poor body posture. These issues can be avoided by careful lighting design that meets occupants' visual requirements.

Standards and codes give recommendations and guidance on indoor artificial lighting, addressing lighting design, health, visual comfort and performance, individual requirements and emergency lighting. However in practice indoor lighting is not always designed or installed to standard recommendations. This can lead to various unwanted effects on occupant health, wellbeing or productivity.

BRE can provide specialist post-occupancy evaluation of artificial lighting to identify causes of problems and recommend solutions. Key aspects of the indoor luminous environment include, the amount of light (illuminances), the uniformity and distribution of light, the sequential experience of lighting in different spaces, the colour of light and room surfaces, glare, flicker and potential problems using display screen equipment.



The many forms of investigation used in post-occupancy evaluation of lighting include computer modelling. Here the commercial office shown in the top image has been rendered with computer modelling in the middle image – with the illuminance distribution levels revealed in the lower image

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