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LIGHTING SPECIAL

LIFE AFTER DARK

How exterior lighting is contributing to the night-time environment

ILLUMINATION IN HEALTHCARE PREMISES

LIGHTING'S NON-VISUAL EFFECTS ON HUMAN BEHAVIOUR

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Thinking outside the box

As the nights continue to draw in, we find ourselves outside in the dark for longer. With that in mind, exterior lighting – and its function in the public realm – becomes a key element of building design.

The growth of the night-time economy, as well as the understanding that lighting can be not only functional, but also improve public spaces, have steered designers towards creating more nuanced after-dark environments.

On page 4, we explain how lighting consultant StudioFractal – which was responsible for the King's Cross Square lighting scheme – tries to replicate the range of brightness values that make us feel comfortable in daylight. To ensure a lighting narrative and encourage exploration, it has connected interior and exterior spaces at its recent London Wall Place scheme.

SLL's new *Lighting Handbook* includes several chapters on exterior lighting design. As Paul Ruffles points out on page 7, this is not just about lux, but about providing the right amount of light, exactly where it is needed.

Our CPD, on page 19, explores this specialist area further, as well as other new chapters of the handbook.

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Conquering outer space

A more nuanced approach is changing the face of exterior lighting, as **Jill Entwistle** discovered with a recent StudioFractal project in the City of London

It is not so long ago that exterior lighting was a rather crude affair. Generally, it relied on street lighting and, where it involved buildings, a frequently cavalier use of floodlights that blasted light indiscriminately at façades, with little heed to architectural detail.

That it has become a more considered area of lighting in recent years is down to a multiplicity of factors – for one, a more sophisticated understanding and appreciation of lighting generally. The growth of the night-time economy, and an appreciation that lighting can not only be functional, but also increase the attractiveness and atmosphere of public spaces, is another.

The development of LEDs and the miniaturisation of luminaires have also enabled more controllable, discreet and integrated lighting, and made lighting public spaces a more energy-efficient proposition. (That they have also facilitated an often random and ill-judged use of coloured light is a whole other discussion.)

One of the remaining battles is overlighting, largely a result of local authority fears of litigation or a constabulary belief that extreme illumination equals less crime. Growing awareness of light pollution may mitigate some of the worst excesses, but security lighting, sports lighting and, especially, the proliferation of ferociously bright LED signage still blaze into the night.

While politely argued skirmishes over lighting levels for piazzas and other pedestrianised areas persist, it seems the case for subtlety is, literally, gaining ground. The general preoccupation has always been with horizontal illuminance – how much light can be squirted on the ground. However, the answer often lies in vertical illuminance, which affects how bright the space feels. Diminishing reliance on the bollard or pole-mounted flood – and increasing use of street furniture and architectural elements, such as handrails and steps, to house light sources – have led to many more layered, visually stimulating and conducive spaces, which encourage social gatherings.

'Our daylit world is full of brightness and shadow, and we feel more comfortable in a world where a range of brightness values allow us to interpret and navigate our way instinctively,' says Tim Downey, managing director of lighting consultant StudioFractal, which was responsible for the King's Cross Square lighting scheme and, more recently, the exterior (as well as interior) illumination of the newly refurbished Royal Opera House. 'As architectural lighting designers, we have long argued for an approach to after-dark lighting that replicates this range of brightness values, to help create a more nuanced night-time environment.'

StudioFractal's recent scheme for London Wall Place, a new destination in the City of London, is an exemplar of this more refined approach. The landscaped public realm sits between two statement office buildings designed by Make Architects. Make also reinstated the site's historic grids, bridging two existing heritage structures – the remains of the 12th-century St Alphege Church and a section of the original London Wall – with newly created pedestrian routes and a series of landscaped gardens. Uniting the new development is an unusual cladding

London Wall Place used a varied material palette that included stone, metal, water and plants

Left: Concealed lighting has a mix of colour temperatures depending on materials and planting

> "We wanted to understand how little light we could use that would still allow people to navigate safely, but get a sense of solitude and tranquillity"

– an iridescent coating of concrete and faience that reinterprets the knapped flint of the site's Roman and Saxon remains.

StudioFractal was given a varied remit: an acre of public space that included landscaped gardens, historic ruins, commercial and retail facilities, and multilevel pedestrian routes.

The detailed lighting strategy, knitting together commercial lobbies, gardens and the reimagined High Walk linking to the Barbican, was designed to enable views through the project, ensuring veiling reflections in glazing were avoided so interior and exterior spaces were connected. The layered scheme combines direct and reflected lighting. 'It creates a softly undulating visual environment, making use of light, shadow, reflection and projection to complement and enhance the material palette of stone, metal, water and planting, and to encourage exploration,' says Downey.

A hierarchy of concealed light sources was developed and located within architectural detailing, with a mix of colour temperatures according to the materials and planting. The aim was to draw the eye between historic and contemporary forms and materials, and invest the gardens with a serene, contemplative feeling.

'We were interested in creating a night garden, and wanted to understand how little light we could use that would still allow people to appreciate the gardens and navigate safely, but, nevertheless, get a sense of the tranquillity and solitude,' »

Cladding with an iridescent coating of concrete and faience unites the development

The High Walk linking to the Barbican enables views through the project says Downey. 'Once our eyes are properly night adapted, it's amazing how much we can see by the light of the moon. We had an interesting palette of materials, and we wanted to develop a scheme that allowed the different textures and tones to be seen.'

High-level wall washing is integrated within the building forms to create a backdrop to the new structures and material – again, drawing the eye across the project and into the interiors. High-level spotlights illuminate the planting and the gently moving water feature, and project gobos on to the walkway below.

Warmer, low-level lighting directs pockets of brightness across the historic stonework, contemporary Corten steel, GRC building columns, and the low-level greenery and walkways. 'We were careful to avoid glare and present illuminated surfaces against silhouetted forms, creating a playful and atmospheric series of spaces,' says Downey.

There is a degree of animation from the lighting. Reflections of moving water play on sections of the soffits, while bespoke lighting integrated within the High Walk continues a rhythm of light and shadow.

'While the lighting standards encourage a creative approach, they only provide a small range of illumination values to work to,' says Downey. 'So how these standards are interpreted becomes very important – a lack of imagination generates flat, even and uninspiring lighting.

'For London Wall Place, by creating a lighting strategy constituting layers of light that treated each element separately, we demonstrated to the client that this would create a cohesive, visually interesting environment that still satisfied the technical requirements of illumination levels and uniformity.' **CJ**

NEW SLL GUIDANCE

As well as several chapters that address the exterior environment in the 2018 *SLL Lighting Handbook* (see page 7), the Society has just updated and reissued its Factfile 7, *Design and Assessment of Exterior Lighting Schemes*. This is aimed at planners and designers, to help them in producing and assessing schemes against potential planning criteria, such as minimising sky glow or reducing impact on wildlife. Showing planners that you have complied with their recommendations will reassure them that your scheme will sit well in the night-time environment – it's free for them to download.

The SLL is about to publish its new Lighting Guide 19 – *Lighting for Extreme Conditions*. This, as its title implies, covers all the extreme and peculiar climatic and ambient environments into which we try to put lighting. It is an expansion of what was a new chapter in the handbook on the same topic. The handbook chapter, and the expanded content of the new guide, don't just cover extreme heat and humidity or freezing conditions, but also explosive environments – in process and petrochemical plants, for instance.

In addition, it covers the salty conditions experienced at the coast, as well as straightforward immersion in water often experienced in pools and tanks. Many interiors also have extreme environments that need specific and appropriate lighting – such as cold and freezer rooms in factories and large supermarkets – and many production areas have special requirements because of potentially corrosive atmospheric solvents or vapours.

For details of all SLL publications visit www.cibse.org/SLL

The ancient remains of St Alphege Church

Salters' Garden with a section of the old London Wall

Turning insight out

The SLL's guidance on exterior lighting ranges widely in application, from façades and public spaces to roads and workplaces, as Paul Ruffles explains

The 2018 *SLL Lighting Handbook* has several chapters that address the exterior environment, including external workplaces, architectural lighting, roads and security.

As with interiors, lighting design for the exterior environment is not just about the lux – it's about where the light goes and how much you use for each surface or part of the scene. Providing the right amount of light just where it is needed, for lighting a task and for effect, avoids unnecessary energy use and possible harmful effects to wildlife and people.

Perhaps the most straightforward chapter is the one on external workplaces. This covers open spaces, such as goods yards, where vehicles and workers must safely coexist, to more localised areas – loading docks, for instance, where vehicles and workers are in proximity.

Some external work spaces are spread over a large area – for example, where forklift trucks are moving around, and the operator needs to see obstacles in their path, as well as read identifying information on the sides of loads that they need to pick from stacks or vehicles.

Other areas are more localised – sets of valves on petrochemical plants, for instance – or are required for detailed maintenance work. As with interior lighting, the designer needs to choose and position luminaires in relation to each task, to provide the required amount of light while avoiding disabling or distracting glare.

The large new chapter on exterior architectural lighting is a visual feast, with many high-quality images demonstrating how to light a range of building types successfully using different techniques. This covers many ways to integrate lighting into façades, as well as the techniques for their full or partial floodlighting.

With a new building, there is scope to integrate the luminaires and their associated wiring into the façade design. This not only makes the design more coherent, but makes it economic to install. With an existing building, integration is more difficult, especially if the building is listed. The chapter offers guidance on many different ways to light an old frontage, from small fittings on windowsills to hiding them between features, and we hope it will encourage people to move away from the 'throwing light at a building' school of façade lighting.

"We hope to move away from the 'throwing light at a building' school of façade lighting"

The chapter on road lighting is deliberately entitled 'Roads and urban spaces' because it covers all aspects of lighting the urban streetscape. Having said that, the guidance on lighting roads and streets is more comprehensive than other similar guidance. Too often, people emphasise the lighting of the traffic parts of our road – the driving surface – while neglecting the pedestrian areas and surrounding buildings, verges and landscape.

As with interiors, the SLL believes the external spaces of our towns and cities should be lit well for people to work in and move through safely while appreciating the lit external environment. Many public squares and parades now integrate lighting into street furniture, such as seating and planters, to provide practical mounting locations within open spaces and flow light over surfaces. There is often a need to provide localised lighting for steps and stairs between areas at different levels.

Security lighting is an interesting topic because it combines a need to understand where the lighting is going in relation to people and cameras covering various features, such as fences and patrol routes. The positioning of lighting in relation to security staff and a possible intruder is important. Ideally, the security staff need to remain invisible or obscured from the view of the intruders, while the intruders need to show up well against their background and any security barriers. The use of directional lighting, differential brightness and, perhaps, semi-silvered glass in windows might assist in achieving this.

The handbook also looks at commissioning and maintenance. It is very important that exterior lighting systems – often subject to wind, rain and freezing conditions – are commissioned correctly and set to work in a fit state. They must also be maintained in a suitable way so they retain their output and, for directional luminaires, their angle of aim.

Some content in the handbook chapters was based on the 2016 SLL *Lighting Guide 6 – The Exterior Environment*, although it adds much new content. This, in turn, will feed back into an expanded future edition of LG6.

Of course, SLL coverage of external lighting does not stop here. Aspects of exterior lighting are also examined in LG4 on sports lighting – for example, the various levels needed for a range of outdoor sports training and competition, and the more detailed requirements for TV coverage. LG15, on transportation, also covers those exciting external areas around airport terminals, as well as the less spectacular – but more common – areas in and around bus and rail stations.

■ See the CPD on page 19 of this supplement for a detailed overview of the changes in the *SLL Lighting Handbook*.

■ **PAUL RUFFLES** is principal at Lighting Design & Technology

Lighting by Whitecroft at Queen Elizabeth University Hospital

Alight and well

Lighting of healthcare environments is moving beyond clinical necessity. **Andrew Bissell** examines the critical need to consider the non-visual, as well as the visual, aspects of illumination

Historically, lighting healthcare environments has focused on the clinical tasks that take place in the various spaces within hospitals and surgeries. This has led to a very precise and numerical approach to the lighting.

While there has been knowledge and understanding of the non-visual benefits of daylight and electric lighting, the needs of the medical staff to perform their duties have come first – and, too often, have been the only consideration. Has this changed and, if so, why?

Healthcare premises – and, in particular, hospitals – are among the most complex environments to light. This is because of the variety of people's needs and the large number of different spaces. It is obvious to say that the visual needs of the medical staff must be addressed, but there are also the needs of the non-medical staff, patients and estates teams to consider.

Added to this are the 50 and more different types of spaces and task areas, including multi-bed wards, single-bed wards, critical care, nurses' stations, offices, receptions, theatres, prayer rooms, laboratories, laundries, and so on.

The new *SLL Lighting Guide 2 – Lighting for Healthcare Premises* (LG2) has more than eight pages of numerical criteria for lighting these varied spaces. This is more than any other sector-specific SLL lighting guide, and reflects the complexity and diversity of these environments.

Fortunately for lighting practitioners, there are another 90-plus pages that deal with the key drivers when lighting each type of space and what each type of user requires.

While LG2 has always been a critical component in the lighting guides, now, more than ever – as lighting installations move beyond simple numerical solutions to complete visual tasks – the text and research behind the guidance need to be understood and adopted.

It is perhaps not surprising that, in a sector where budgets are tight – including engineering and design fees – solutions, too often, focus on the basic numerical requirements. As our knowledge of the benefits of non-visual lighting improves, however, using the numbers without reading the text or the associated research will be to fail the users of healthcare premises.

Some areas are more easily quantifiable than others, of course. Lighting to satisfy medical needs is critical, for instance, but the criteria for achieving

> "We are now lighting in an age when the wealth of information about the benefits of non-visual light means we can no longer ignore those aspects"

this are relatively simple, and the associated solutions can be rudimentary in luminaire and engineering terms.

Typically, there is a requirement for an average and maximum lux level, a glare rating and, finally, a colour-rendering target that almost all types of modern lamps can satisfy and exceed. In some areas, there may also be a luminaire hygiene requirement or impact rating – but, again, these criteria are easily achievable. Moreover, all are easily measured and checked. This means that a standard or agreed set of criteria can be designed to and delivered, such that a contract can be easily assessed as having been completed.

By comparison, while a patient has visual needs – for example, to read, get dressed, bathe, and so on – there is also a requirement to create a relaxed environment to reduce anxiety and stress. Rather than satisfying a numerical medical need, this relaxed environment requires a very different approach to the lighting and interior design. Views of nature and access to daylight have been shown to improve recovery, and there is a general preference for natural light over electric light.

The difficulty with this non-visual (or emotional and biological) need is that the solutions are more involved and it is more difficult – if not impossible in some cases – to demonstrate that the design and delivery will reduce anxiety or improve recovery. Whether a design and installation have created a relaxed environment could be subjective and, therefore, difficult to place into a contract.

However, we are now lighting in an age when the wealth of information about the benefits of non-visual light means we can no longer ignore those aspects. We need to find a way to address both the numerical solution and subjective design.

When not undertaking medical procedures, the staff also need a lit environment that is relaxing, homely and supports their shift patterns. What is particularly difficult here is that not everyone will have the same shift patterns; those arriving to work in the early evening are starting their day when some – and, in particular, the patients – are at the end of their day.

When you consider the shift patterns alone, you have to question if it is even possible to take them into account. Perhaps, where the staff and patients share the same spaces, the patients' needs must come first to maintain their circadian rhythms. Where the staff predominantly occupy spaces, then their needs and circadian rhythms are given precedence.

Another group to add to the already congested list is that of visitors. These people are, or at least should be, healthy, so the lighting does not need to cater to improving their recovery, for example. Their daily light cycle is likely to be in line with daylight, so they will have similar non-visual needs to the patients. What is important for the visitors is to enter a space that makes them feel good and that gives them some privacy with their friend or family member.

When visitors experience the right type of environment, they are relaxed, which is conducive to a better bedside manner; this, in turn, helps improve the recovery of the patient. The typical medical numerical solution does not provide such warmth and personal feeling.

The final group of people who require lighting to do more than just satisfy a numerical, medical set of criteria is the estates team. They want the lighting to achieve all of the above, but they also have to maintain and manage the lighting »

Chase Farm Hospital, Enfield

installation, including fixing damaged equipment, sourcing replacement parts years after the contract is complete, recommissioning the controls when drivers are replaced, and so on. They are also continually looking to reduce the energy consumption.

These pressures potentially conflict with the concept of delivering a more involved, personal and complex lighting solution. Satisfying the visual and non-visual needs of all groups of users may lead to a higher number of products, more wiring points and more complicated controls.

For an estates team, a smaller – not larger – selection of luminaires is preferred; fewer lamp-module types make it easier to replace parts; fewer wiring points reduce clutter in and above the ceiling; simple controls with switches rather than 'scenes' eliminate user complaints; and less automation or dimming reduces commissioning revisits, and staff or patient grumbles.

Having discussed the key challenges, can we say that we are seeing – or are likely to see – a change towards a visual and non-visual solution?

From conversations with clients, architects and contractors involved in the sector, the desire is certainly there to move away from healthcare premises that look too clinical, too bright and too uniform – but cost and complexity of controls are regular items for discussion. Those factors should not be a reason to retain the status quo, however. Instead, they should be seen as a challenge to the designers and manufacturers to reinvent the sector. **CJ**

A linear accelerator for radiation treatment at the Dutch Cancer Institute

> "From conversations with those involved in the sector, the desire is there to move away from healthcare premises that look too clinical, too bright and too uniform"

LG2: ACCESS AND AUTHORS

SLL Lighting Guide 2 – Lighting for Healthcare Premises **(LG2) was published in September 2019. Members can download it in pdf form, free of charge (standard price £47), from the CIBSE Knowledge Portal. It is also available in book form for £26 (CIBSE members) or £52 (standard price).**

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Kinghorn Cancer Centre

Panel beating

An inferior variety of LED panel has become ubiquitous in offices, but they are a glaring error, argues Alan Tulla

I read a traffic survey that said the M25 was the most popular motorway in Britain – the justification being that it is used more than any other route. I hear the same argument when I investigate complaints about lighting in offices. 'There's nothing wrong with the panels, mate. They're used in offices everywhere.' It's not difficult to see the holes in this argument.

The fittings in question are 600 x 600mm LED panels; more particularly, the inferior variety that can sell for less than £30. Arguably, you can achieve the same illumination level as 80W of fluorescent using 35W of LEDs. You also get longer life (no tubes to replace), LEDs are flicker free, and you can replace them one for one, fluorescent to LED. Being recessed and 600 x 600mm, they also simply drop into the space of any ceiling tile. So, what is wrong with illuminating an office just with 600 x 600mm LED panels?

Well, the one thing you don't get from them is good lighting. Also, in a large office, the installation probably won't meet BS EN 12464, concerning glare. For these reasons, it's worth examining in more detail the specific objections to this type of luminaire.

"There are plenty of good-quality LED panels that control the light at higher angles, but you need to specify them"

The first applies to recessed luminaires in general – they can't put light on the ceiling. Unless you have highly reflective flooring and desktops, the ceiling will appear unnecessarily dark. Coupled with a bright light source, this contrast is a major contributor to glare. The remedy is to direct more light onto the ceiling. There are several ways to do this, including using surface-mounted panels where the sides are used to direct light across the ceiling. An alternative is to use suspended direct/indirect luminaires, but you need more than a standard 2.5m ceiling height to achieve a good result. If you must use recessed panels, they can be supplemented with wall-mounted or freestanding uplights. You might even be able to persuade the architect to fit light shelves. But plain recessed panels alone are never ideal.

Another issue with panels is light distribution. Many of you will remember Cat 2 louvred, or 'egg crate', luminaires, which limited light above 65 degrees. Strangely, hardly anyone asked for Cat 1 or Cat 3 – I suspect because they couldn't be bothered to read any other pages of the excellent SLL LG3 (*The Visual Environment for Display Screen Use*, now withdrawn). Its content is now found in the *Lighting Handbook*. Many budget-range LED panels emit light at higher angles than louvred ones. A common complaint from staff is that the panels 'shine in your eyes'.

I should say that there are plenty of good-quality LED panels that control the light at higher angles, but you need to specify them. Look for 'micro-prismatic' or screen use in the data sheet.

I came across an example of this effect when I visited some offices the other day. One floor had old louvred, fluorescent luminaires, while the one below had been refurbished with new LED panels and a lick of paint. It was surprising how much more comfortable the older, louvred fittings were; some staff even wanted them back. Some staff also said the space was gloomier – it was just that the LED panels were too bright. The solution is good lighting design rather than simply swapping one fitting for another.

Finally, I come back to glare and how we calculate it. The CIE Unified Glare Rating (UGR) is referred to in the *SLL Code for Lighting* and the *Lighting Handbook*. There are limiting values for it, such as UGR 19 for office applications and UGR 25 for factories. The lower the figure, the less glare is implied. Installations with low UGR tend to have luminaires close together, because the light is directed downward and less is emitted at higher angles. Several factors contribute to glare, including viewing position, how many fittings you can see, the geometry of the space, and background luminance. One critical factor is how 'bright' the luminaire is.

The UGR calculation assumes that the viewed surface of the luminaire is uniform, no matter at what angle you see it: the diffuser is homogeneously illuminated by the LEDs. However, many panels feature LEDs arranged in strips or that have an intense central band with the surrounding metalwork considerably less luminous. The same amount of light spread over half the viewed area doubles the luminance, so is more glaring. There is a caveat: some panels have lenses over the LEDs that control the beam angle and, in this case, the viewed luminance might be less than the calculation would imply. Unfortunately, the CIE metric does not consider this. Until it does, there is not an easy solution, except to use your professional judgement. (For more on this specific topic, see SLL's FactFile 15: *The Importance of Glare and Calculating UGR*, July 2019).

Panels by themselves won't provide good lighting under any circumstances; adequate, maybe, but that's not what we are here for. After all, the first aim of the SLL is, 'to promote the benefits of good lighting, especially in the built environment'.

ALAN TULLA, FSLL, is an independent consultant, and a former SLL president

Have you seen the **light**?

"If you always do what you've always done, you'll always get what you've always got."

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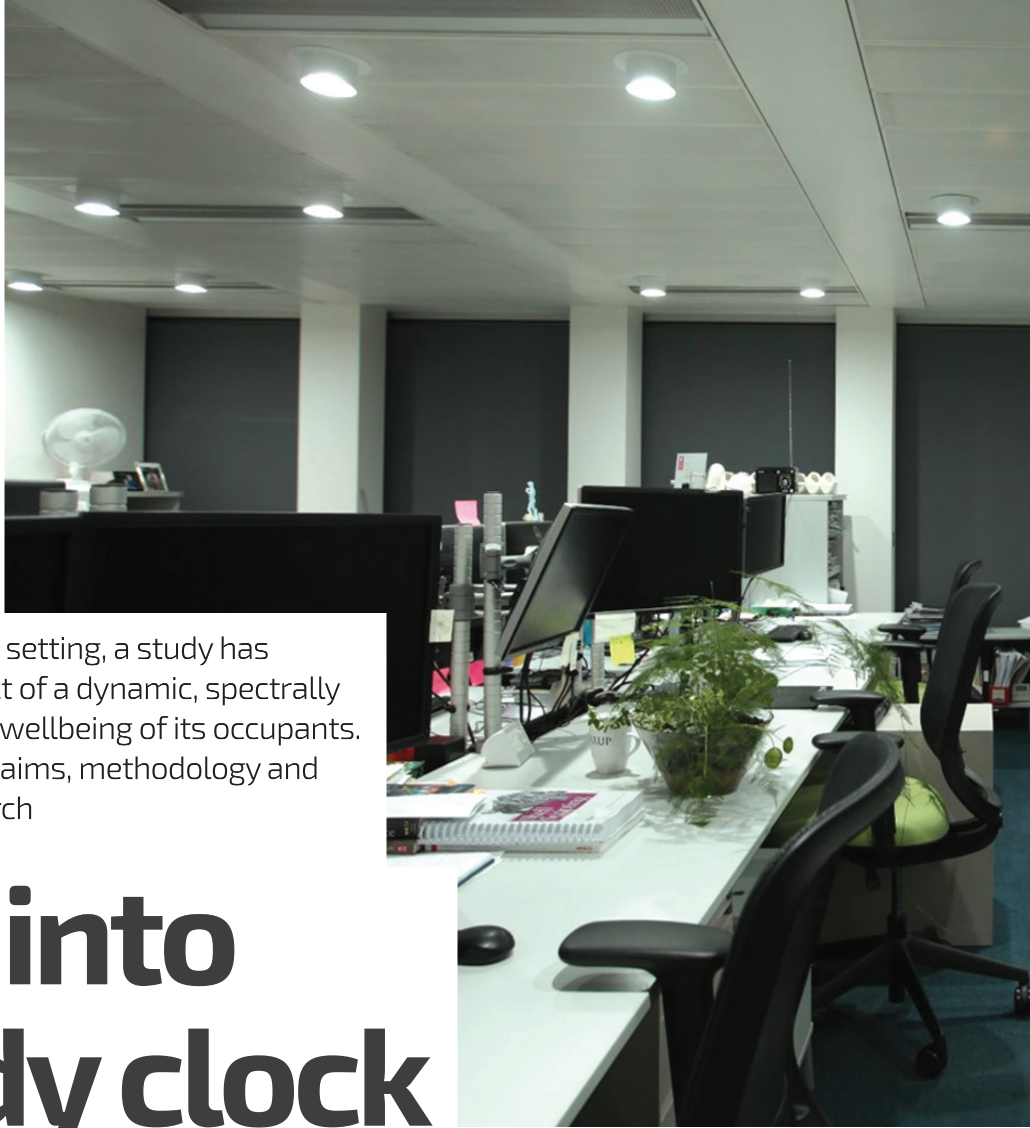

For the first time in a real office setting, a study has been carried out into the impact of a dynamic, spectrally tunable lighting system on the wellbeing of its occupants. Rohit Manudhane outlines the aims, methodology and initial conclusions of the research

Tuning into the body clock

For millennia, the modern human visual system evolved solely under exposure to natural daylight. This is a mixture of light from the sun and sky, containing energy at all wavelengths in the visible spectrum.

Since the invention of the candle, at least 2,500 years ago, humans have become more reliant on artificial lighting technologies – and increasingly so in the past century, since the development of electric light. This has led to more activities being performed indoors, significantly shortening the daily exposure to natural light.

In the design of illumination for indoor spaces, only well-established visual effects of light – such as illuminance, glare, chromaticity or correlated colour temperature (CCT), and colour rendering indices (CRI or TM-30, for instance) – have traditionally been considered. However, there is now a new drive to characterise lighting in terms of its non-visual effects on human behaviour.

This follows the recent discovery, in the eye, of the intrinsically photosensitive retinal ganglion cells (ipRGCs) as the origin of the non-visual pathway that entrains biological rhythms to the light/dark circadian cycle.

Non-visual pathway

This non-visual pathway is responsible not only for regulating the circadian rhythms of body temperature, melatonin secretion and the overall sleep/wake cycle, but also for modulating cognitive function, attention and mood. Although it has long been known that the entraining light signal emanated from the retina, it was not until the discovery of the ipRGCs – and the characterisation of the melanopsin photopigment they contain – that the importance of spectral variations in light for eliciting non-visual effects was recognised fully.

The spectral sensitivity of melanopsin peaks at 480nm, midway between the short- and middle-wavelength cones, but because of the relative broadband tuning of photopigments, it overlaps with that of all four classical photoreceptors. Modulation of the short-wavelength ('blue') content of light has been shown to affect various physiological measures, such as melatonin suppression, alertness, thermoregulation, heart rate, cognitive performance, and electroencephalographic dynamics.

The effectiveness of a given light spectrum in activating the non-visual pathway may be quantified by its melanopic lux, the spectral irradiance weighted by the melanopsin spectral sensitivity function and integrated over wavelength, or by functions of the same. So, melanopic lux is an appropriate characteristic of illumination to consider in addition to visual factors such as photopic lux or CCT.

"Currently, the most common artificial light sources are fluorescent lights and white LEDs, which are all static sources with spectra very different from natural daylight"

The section of the Arup London office with Ledmotive's spectrally tunable lighting system installed

Tunable lighting

Currently, the most common artificial light sources are fluorescent lights and white LEDs, which are all static sources with spectra very different from natural daylight. The recent invention of narrow-band LEDs enables the development of spectrally tunable light sources that can generate illuminations with arbitrary spectral shapes, and so mimic daylight spectral patterns or create tailored dynamic spectral sequences according to end-user needs.

Light condition	Duration	Dates	Photopic lux	Melanopic lux	CCT
Baseline (fluorescent lights)	Two weeks	18 February to 3 March	Static (350 lux)	Static (160 lux)	Static (3,534K)
Sequence A	Two weeks	4-17 May	Changing (500 lux-300 lux)	Changing (450 lux-160 lux)	Changing (6,000K-2,500K)
Sequence B	Two weeks	18-31 March	Static (350 lux)	Changing (450 lux-170 lux)	Static (3,534K)
Baseline (mimicking fluorescent lights)	One week	1-7 April	Static (350 lux)	Static (160 lux)	Static (3,534K)
Real-time daylight matching	Two weeks	8-19 April	Changing	Changing	Changing

Table 1: Summary of the trial's light conditions

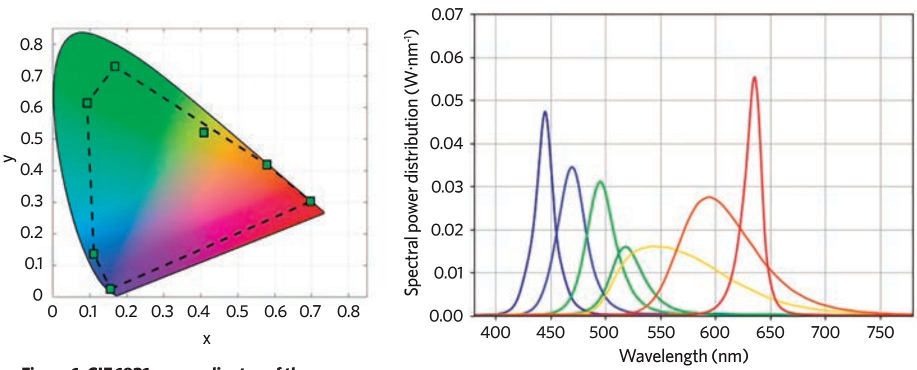

Figure 1: CIE 1931 xy coordinates of the seven channels that define the colour gamut (left) and the preset SPDs of the seven LED channels (right)

Previous studies have compared the performance of individual subjects under different artificial lighting conditions. Such studies, though, have used only two types of white light, both fixed in time – cool, blue-enriched fluorescent light and warm fluorescent light – and have not exploited the novel spectral flexibility offered by multichannel LED light sources.

In this study, and for the first time in a real office setting (Arup's London headquarters), the behavioural effects of a dynamic, spectrally tunable lighting system were investigated. The study included assessments of alertness, mood, sleep quality, performance and mental effort of the occupants, plus other responses to different dynamic illumination conditions, in a nine-week intervention.

The aim was to assess whether sculpting different spectral power distributions (SPDs) of light may bring measurable benefits in terms of wellbeing and productivity in an indoor workplace. More generally, we wanted to understand better the behavioural effects of different lighting conditions in indoor environments and raise awareness of the importance of a circadian lighting approach.

The area selected for the study, shown in the image above, measured around 160m^2 and involved the working desks of 24 people. A set of 36 downlight luminaires containing Ledmotive (model VEGA07) tunable light engines were installed into ceiling panels, alongside the pre-existing fixed fluorescent light tubes. These comprised 48 commercial monochromatic LEDs arranged in seven channels, each with a distinct peak wavelength, spread over the visible spectrum. External light sources were blocked by covering the windows along one wall completely. »

Study time

For the first two weeks, the study was conducted solely under the pre-existing traditional fluorescent lights, to provide a baseline. The second two weeks were spent under spectrally tunable light sequence A, and the third two weeks under spectrally tunable light sequence B. During the fourth one-week period, the spectrally tunable lights mimicked the baseline fluorescent output, and in the final two weeks, they mimicked real-time daylight patterns.

The regular fluorescent sources – the light conditions set for the first two weeks – have a familiar spiky spectrum (see Figure 2, top graph), totally different from natural daylight. The office's fluorescent sources had a CCT of 3,550K, and typical values of photopic lux at the desktop were around 350 lux. The melanopic lux for this light was about 160 lux at the desktop. During the seventh week, when mimicking fluorescent lights with the spectrally tunable light source (see Figure 2, bottom graph), the light generated had the same parameters: CCT of 3,550K, photopic lux of 350 lux and melanopic lux of 160 lux at the desk level.

Light sequence A had temporally changing melanopic lux, photopic lux and CCT during the day, with: melanopic lux falling from a high of 450 in the morning to a low of 160 in the evening; photopic lux falling from 500 in the morning to 300 in the evening; and the CCT changing from cool (6,000K) to warm (2,500K) over the same interval. Light sequence B matched light sequence A in terms of its changing melanopic lux, but kept constant photopic lux and CCT at levels matching the baseline fixed fluorescent lights.

High melanopic lux in the morning is thought to lead to better attention and higher arousal, while low melanopic lux in the evening is suitable for relaxing and for better sleep at night. In this experiment, light sequence A was designed to change in CCT from cool in the morning to warm in the afternoon, and with photopic and melanopic lux values changing from high in the morning to low in the afternoon (see Figure 4).

Sequence B was designed with the same visual parameters as baseline (same CCT and photopic lux) but with changing melanopic lux values during the day (see Figure 5). By comparing sequence B with baseline, the experiment compared the effects of changing melanopic lux alone, with the other parameters remaining the same. With sequence A, we were able to

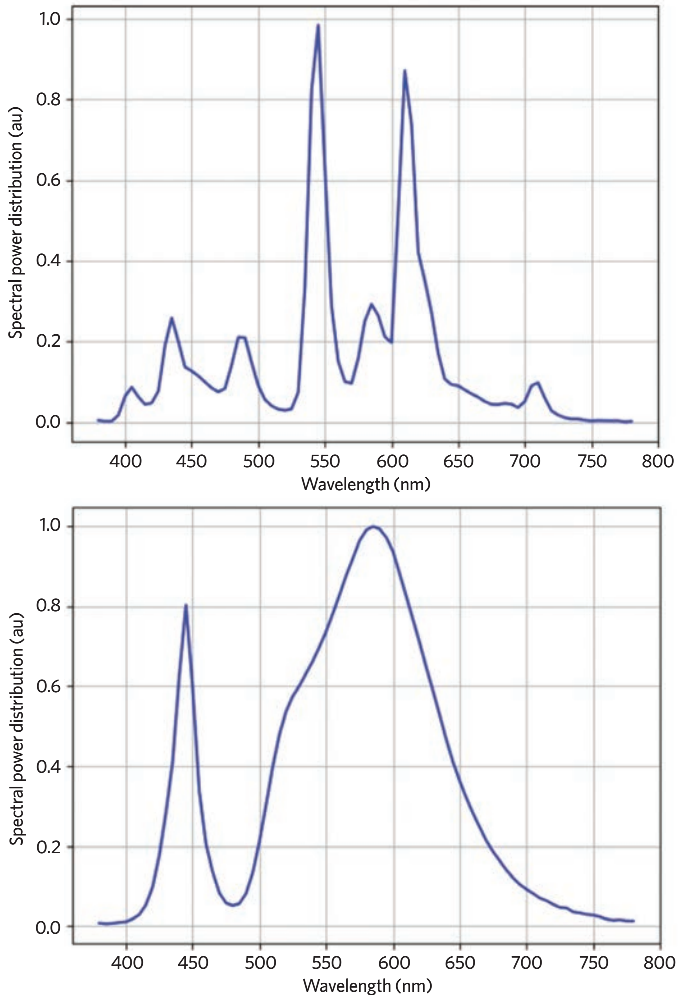

Figure 2: Baselines – the SPD of the real fluorescent lights (top) and the SPD of the spectrally tunable light engine (bottom). Both measured spectra have the same CCT of 3,550K, the same photopic lux of 350 lux, and the same melanopic lux of 160 lux at desk level

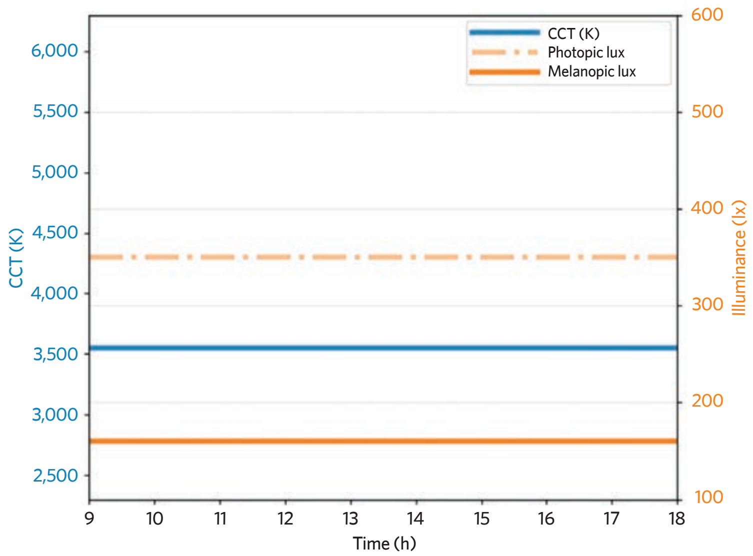

Figure 3: In an office setting with only fluorescent sources, light indicators – such as CCT, photopic lux or melanopic lux – coming from the light fixtures remain static during the whole working day

"Those taking part in the study preferred the variability and tunability of lights" test not only the melanopic lux effect, but also the effect of concomitant changes in CCT, as the visual comfort and overall experience that the light fixtures evoke is important for wellbeing, too.

Measuring effects

Subjective and objective measurements were taken throughout the study. As part of the subjective assessment, participants were asked to complete web-based questionnaires at four time points each weekday (on waking, mid-morning, mid-afternoon and before going to sleep) and at two time points (waking and before sleep) on each day of the weekend and holidays. As an objective measure, they were asked to wear, 24/7, a smart watch that keeps track of body temperature, illuminance exposure and activity levels. They were also asked to complete a five-minute visual attention task at two timepoints each weekday. This was a continuous performance task that assessed sustained attention and response time, implemented via a web-based JavaScript application.

During the trial's final two weeks, a calibrated spectrometer was installed in the building's roof to measure daylight spectra every few seconds. Connected to a Raspberry Pi, the spectrometer sent the spectral information to the lighting system control unit, which very rapidly found the channel weights that gave the best spectral fitting to the target SPD. Any change in SPD or illuminance in the outdoor environment was smoothly translated inside the office.

The final results need further analysis and elaboration, but the following are the initial conclusions drawn from the study:

- Those taking part in the study preferred the variability and tunability of lights, especially in areas with minimal daylighting
- They also preferred the variability in electric lighting that reflected real-time daylight conditions effected by a link to outside (in this case, a roof-mounted spectrometer connected to the lighting control system)
- Participants also did not perceive a higher CCT of around 5,500K as being too cold or unpleasant. This is an aspect of LED source specification that can be explored on future projects. Cooler colour temperatures have the benefit of imparting marginally higher lumens/W, boosting the energy-savings aspect
- Higher CCTs also lead to a higher melanopic ratio, which might be beneficial for projects targeting the circadian lighting feature in the Well Building Standard criteria. **CJ**

ROHIT MANUDHANE is an architect, daylighting and lighting designer at Arup. Other project members included: Anya Hurlbert, professor of visual neuroscience at Newcastle University; Florence Lam, director, global lighting design, at Arup; Aleix Llenas, researcher at the Catalonia Institute for Energy Research; plus manufacturers Castan Architectural Lighting and Ledmotive

The original research paper can be read at **bit.ly/CJDec19light1**

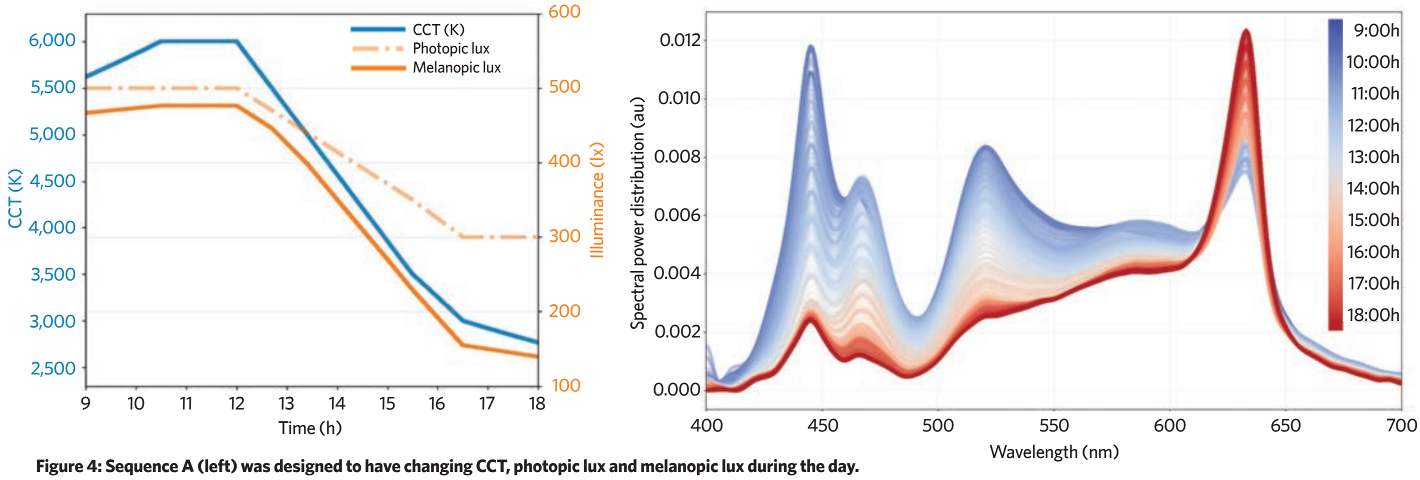

Figure 4: Sequence A (left) was designed to have changing CCT, photopic lux and melanopic lux during the day. In situ measured spectra from sequence A SPD (right), varying from 9am (blue) to 6pm (red)

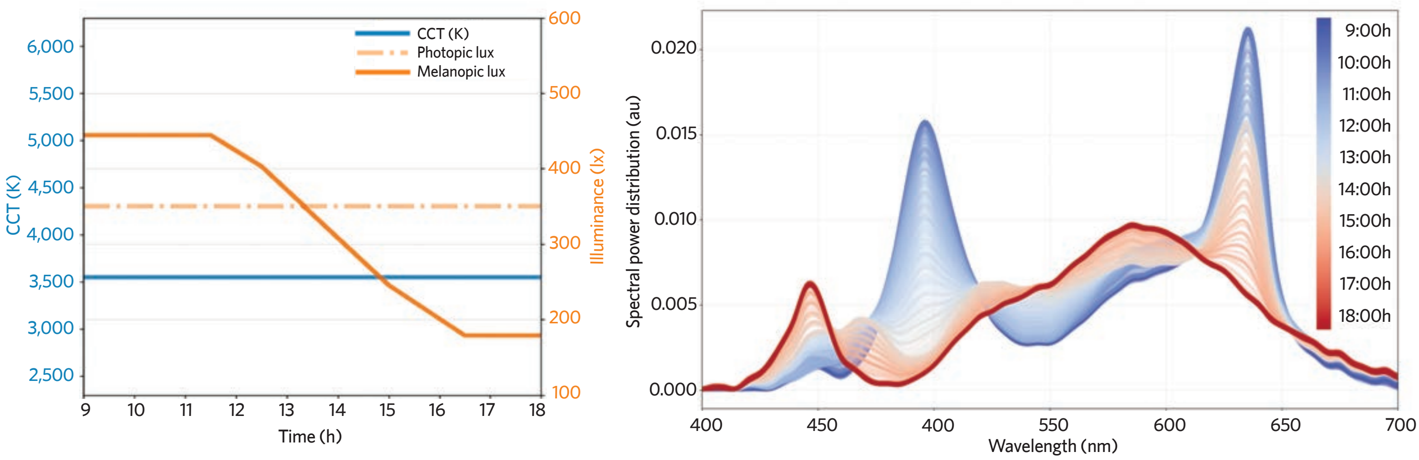

Figure 5: Sequence B (left) was designed to have the same static CCT and photopic lux as baseline throughout the day, but with changing melanopic lux. In situ measured spectra from Sequence B SPD (right), varying from 9am (blue) to 6pm (red)

A spotlight on the 2018 *SLL Lighting Handbook*

This module looks at the new chapters that have been introduced in the revised 2018 edition of the Society of Light and Lighting's *Lighting Handbook*

The recent Society of Light and Lighting (SLL) rewrite of the *SLL Lighting Handbook*[1] is a significant reorganisation, and includes substantial new material to provide a firm focus on the practicalities of day-to-day lighting design and implementation. This CPD will specifically focus on the new chapters that have been introduced in this 2018 edition.

To improve the balance of the handbook, there are significant new materials on technology and practice, and the chapters on light and vision from the previous edition of the *SLL Lighting Handbook* have been moved to the recently revised *SLL Code for Lighting*, which is also due to be published soon. The resulting 480-page handbook includes 13 new chapters and provides a unique, well-balanced reference covering the considerations, technologies, processes and practices that unite to deliver a successfully illuminated environment.

This edition of the handbook was written by an army of volunteer authors, and then reviewed by a wide cross-section of practitioners. Lead author of the *SLL Lighting Handbook* Paul Ruffles emphasises in his handbook presentation[2] that there was a concerted effort to ensure that the review process included younger members of the lighting community who were most likely to have more recently experienced training and applications of new technologies. The 32-chapter handbook is divided into three sections and four appendices and, at first sight, the printed version can present a daunting prospect. However, Ruffles indicates that the book is not designed as an end-to-end read but is suitable to 'dip into' when lighting professionals (known as 'lighters') need to improve, or refresh, their knowledge of particular lighting topics.

The first section considers the 'Fundamentals', and is structured to follow approximately the design right through to commissioning and future maintenance. The second section considers 'Technology', and then the largest part of the handbook, which makes up the third section, considers a selection of 'Applications'. There are important revisions to practically every part of the handbook. However, this CPD article is focusing principally on the new chapters.

Three of the five chapters in the design section are completely new to this edition: 'Lighting design process'; 'Design ethos'; and 'Coordination with other services'.

'Lighting design process' considers why the lighting is needed – for example, it could be to meet any one of a diverse range of needs: for people; for objects in a museum for conservation purposes; for external events at festivals; or for one of the myriad other lighting needs. It also covers some of the key responsibilities that ensure the provision of successful lighting – who commissions the lighting, who is responsible for the lighting, and how to confirm that the final lighting installation meets the need of the end user.

Beginning with the CIBSE code of conduct, the 'Design ethos' chapter goes through how the lighter has a responsibility to the wider society as well as fulfilling the client requirements. The ethical responsibilities align with those of many other professions, and are elucidated in this chapter in terms of considerations such as the Bribery Act; what is expected in tendering procedures; the practicalities of 'equal and approved'

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products; and aspects that will impact the sustainability of the lighting system.

The chapter 'Coordination with other services' is included to help guide the many people coming into the lighting profession from non-engineering backgrounds – such as theatre design, fashion styling or architecture – who may not be familiar with the demands of mechanical and electrical services and the challenges in using the shared space. This includes providing access and integration with other ceiling services, distribution of power cabling, and the interaction of cooling systems and the impact on the performance of lights.

Part 2 'Technology' has been updated extensively and includes two new chapters – 'Light sources' and 'Power to lighting systems' – as well as incorporating significant changes to the 'Controls' chapter.

'Light sources' provides thorough coverage of the whole range of lighting technology that, as may be expected, includes a significant segment on LEDs, their construction, directionality and the type of light emitted. The operational efficacy of LEDs is discussed, and this notably includes temperature sensitivity – as most traditional light source LEDs struggle to dissipate heat, and increasing the temperature at the LED can seriously reduce its light output, it emphasises the importance of the lighting design to maximise heat dissipation from the LED chip. The extensive section on LEDs does not displace coverage of the more traditional lamp types, such as metal halides and discharge lamps, which are included complete with considerations of the peculiarities of each type – even extending to a short section on gas lighting.

The significant changes in the 'Controls' section were driven by the needs of lighters to understand the rapidly advancing area of electronic and digital controls. The energy consumption of a lighting installation can be significantly reduced by the addition of automatic lighting controls. The handbook notes that they are 'essential' for design compliance with current Building Regulations and/or energy performance requirements, although 'lighting performance should not be compromised in the sole interests of energy conservation'. In his presentation, Ruffles reflects that 'many of the problems with the application of LEDs has been to do with the electronics rather than the LEDs themselves'.

The Lighting Energy Numeric Indicator (LENI) is introduced as a reasonable starting point in lighting energy prediction, but notably 'the actual energy savings will be governed by the specific application and human factors'.

The inclusion of a new 'Power to lighting systems' chapter reflects the importance of the rapidly evolving topic. Although it is not an electrical engineering chapter, it outlines the circuit design process, and how cables are installed and run through the building so that lighters are aware that designs must account for the realities of supplying power and routing cables. There is a salient reminder early in the chapter that, no matter how complex a design is, there are two basic requirements associated with the distribution and use of electricity – the safety of people and ensuring that the risk of fire is not introduced. It goes on to describe final circuit distribution protection and effective cable length, something that is both important for emergency lighting and for DC-based systems such as LED lighting. It discusses conventional and modular cabling systems, and the chapter closes with information on distributed power systems, with an overview of DC-based systems including brief information on power over ethernet (PoE) that is based on the available information at the time of writing the chapter.

Figure 1: The light reflectance values as reported on a paint swatch. The light reflectance value ranges from 0 to 100, with 0 representing pure black (that is, not light-reflecting at all) to 100.0, pure white, with all the light being reflected (Source: *SLL Lighting Handbook*)

Part 3 of the handbook, 'Applications', makes up the bulk of the publication and is broken into 22 chapters, as shown in Table 2. This includes a whole range of areas – many that are also covered in more detail in the separate *SLL Lighting Guides* – and four new chapters to provide a lighting design resource that is likely to encompass most 'normal' building requirements.

The new 'Common building areas' chapter includes the generic areas that are found in almost all types of buildings, such as entrance halls, corridors, lift lobbies, toilets, cleaners' rooms and plant rooms. The guidance attempts to give practical information that has previously been absent in standards and guides. So, for example, toilets were previously simply designated as requiring 100 lux, with no specific guidance where this should be measured. This chapter provides recommended lighting levels for the floor, basins and surrounding surfaces, at toilet seat level and over baby changing tables. Similarly, for example, there is increased granularity in the guidance for connecting spaces such as ramps, where it notes that for design purposes, they should be treated in the same way as corridors. However, with an inclined floor and possibly flat areas, it notes that where ramps form part of an exit route, emergency lighting should be provided with additional emphasis on the start and stop of the incline. Another example where the handbook drills down to essential, and practical, guidance is when describing the lighting needs for cleaners'

APPLICATIONS

Common building areas (new in 2018)	**Transport buildings**
Retail lighting	**Extreme environments (new in 2018)**
Industrial premises	**Exterior workplaces**
Educational premises	**Exterior architectural lighting (new in 2018)**
Retail premises	**Roads and urban spaces**
Museums and art galleries	**Security lighting**
Hospitals and healthcare buildings	**Sports**
Places of worship	**Historic buildings and spaces (new in 2018)**
Communal residential buildings	**Commissioning of lighting installations (new in 2018)**
Places of entertainment	**Performance verification**
Courts and custodial buildings (new in 2018)	**Maintenance**

Table 1: The majority of the handbook provides a set of applications chapters that cover most 'normal' lighting applications

rooms that needs 'to provide light on the sink, even when someone is leaning over it, and vertical illumination on any shelving' to allow cleaners, for example, to safely select and then mix up chemical solutions for cleaning. Ruffles has reflected that the more considered descriptions of the lighting needs of such spaces will be fed back to the European standards committees for potential inclusion in future codes.

'Courts and custodial buildings' is a new chapter that provides guidance on what lighting is required in these specialist spaces. It proved challenging to determine the technical provenance for some of the prevailing guidance. For example, some existing court guidance gives maintained lighting levels of 125, 150 and 175 lux for, respectively, defendant's toilet, child witness toilet and judge's toilet. The handbook notes that the government department's figures 'appeared unusually precise and the rationale of why a judge needs 25 lux more in a toilet than a child witness is not explained'. However, the key message was that these figures should be treated as a guide and, as with all design criteria, they should be discussed with the client during design.

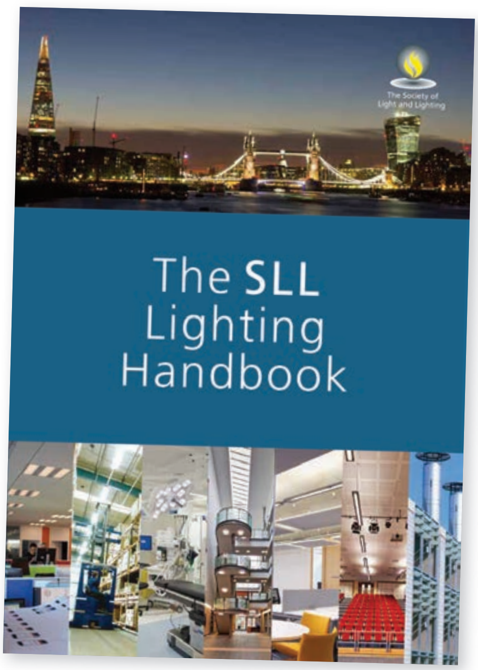
The chapter includes commentary on the lighting requirements for practically all areas that make up courts and custodial buildings, and accounts for not only the aspects that directly have an impact on the visual environment, but also includes wellbeing, security and safety aspects for the inmate, custodial staff and visitors. It notes the importance of lighting resilience, so there is no opportunity for complete failure, and that the electronic control system should not be susceptible to hacking.

A completely new chapter (currently being developed into a separate lighting guide) is 'Extreme environments', which provides contextual guidance on the environments as listed in Table 2. This chapter is a potpourri of environments that are likely to be read in conjunction with one or more of the specific application areas. So, for example, the cold and freezing environments might be applied to applications as varied as an Antarctic research station, a distribution warehouse for frozen foods or a cold store in a local supermarket. Similarly, explosive environments may be applied to disparate applications such as a flour mills, sawmill or laundry – where particulate matter in the air presents an explosion risk – as well as those spaces that contain unstable products, chemicals and gases.

The 'Exterior architectural lighting' environment is an area that has developed swiftly, spurred on by the versatility, controllability and ubiquity of LEDs, and so merits a dedicated new chapter in this rewrite of the handbook. There is, however, far more to successfully designing and applying such lighting than simply determining the lamp type, and Ruffles writes about the demands of this specialist area in a separate article in this Lighting Supplement included with this issue of *CIBSE Journal* (see page 7).

The brief new chapter 'Historic buildings and spaces' provides a commentary on the lighting of heritage spaces, considered in terms of four categories – historic building being converted to a new use; reuse of historic buildings and interiors; historic building preserved 'as is'; and historic or sensitive exterior spaces. The final category relates to spaces such as the gardens around a historic building, the streets in a world heritage city, bridges, ruins or areas of outstanding natural beauty. It notes that, as well as requiring special care in lighting design, the daytime appearance of the lighting infrastructure must also be carefully considered.

The remaining new chapter in the 'Applications' section is 'Commissioning of lighting installations', which makes an important debut in this edition of the handbook. Commissioning is often relegated in both time and resource, as the apparent active work necessarily takes place towards the tail end of many



The latest version of the *SLL Lighting Handbook*

EXTREME ENVIRONMENTS

Cold and freezing environments
Hot and humid environments
Dusty environments
Chemicals and chemical vapours
Submersion: pools, ponds and water features
Wash-down/clean rooms
Marine (onshore, offshore and submersion)
Vibration, impact and vandalism
Explosive environments

Table 2: The new contextual sections on 'Extreme environments' are included as a chapter in Section 3 – Applications

contracts. However, as emphasised in this chapter, although a full commissioning management team may not always be appropriate for projects with relatively simple lighting installations, an appropriate level of commissioning management is always needed. The activities discussed clearly reinforce that the commissioning programme starts well before system installation, with appropriate pre-design assessments, and then runs continuously through to installation handover, development of operation and maintenance manuals, operator training, post-completion checks and adjustments, and seasonal inspections.

And finally, despite their status as appendices, the content of the three new final 'chapters' deliver abundant state-of-the-art information that is worthy of the lighter's attention. This includes an extremely well-considered and illustrated chapter on 'Reflectance and colour', that includes reference to the light reflectance value (LRV), for example on paint swatches in Figure 1, the current thinking on 'Circadian lighting', and a summary of the relevant 'Building Regulations and environmental labelling schemes'.

The 2018 edition of the *SLL Lighting Handbook* is testament to the commitment and enthusiasm of a dedicated volunteer group of lighters, and provides a cornucopia of information produced by several different chapter authors. Inevitably, there is crossover in information across the sections and chapters so, although the printed version is wonderful to flick through, it is very useful to download a digital version of the handbook (free to CIBSE members) so that it can be comprehensively searched with reader software when looking for information on specific topics that may appear in numerous locations.

■ With thanks to Paul Ruffles for the material based on his presentation on the 2018 SLL *Lighting Handbook*, which can be viewed in full at **bit.ly/CJDec19SLLvideo**

■ Turn to page 22 for references.

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Module 156

December 2019

1. **How many new chapters has the 2018 *SLL Lighting Handbook*?**

☐ A 3

☐ B 5

☐ C 10

☐ D 13

☐ E 32

2. **In which chapter does a discussion on 'equal and approved' products appear?**

☐ A Controls

☐ B Coordination with other services

☐ C Design ethos

☐ D Lighting design process

☐ E Luminaires

3. **What do the letters LENI stand for?**

☐ A Lamp Enumeration Number Index

☐ B Liberalised Equipment Navicular Incentive

☐ C Licenced Equipment Neoteric Incompatibility

☐ D Lighting Energy Numeric Indicator

☐ E Local Energy Notional Incandescence

4. **What maintained lighting level is suggested in the prevailing guidance for a defendant's toilet facility in a court building?**

☐ A 100 lux

☐ B 125 lux

☐ C 150 lux

☐ D 175 lux

☐ E 200 lux

5. **Which of these is not explicitly referred to as a category in the 'Historic buildings and spaces' chapter?**

☐ A Historic building being converted to a new use

☐ B Historic building preserved 'as is'

☐ C Historic lighting systems and components

☐ D Historic or sensitive exterior spaces

☐ E Reuse of historic buildings and interiors

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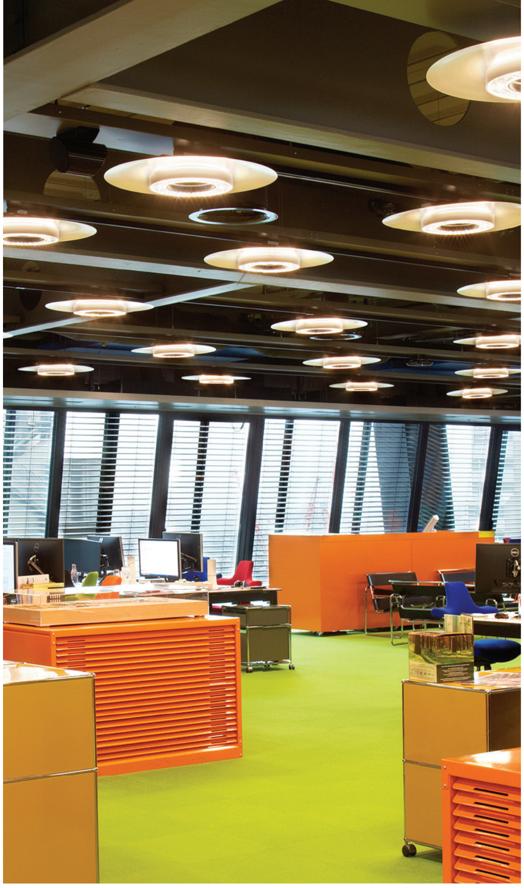
References:

1 *SLL Lighting Handbook*, Society of Light and Lighting, CIBSE, November 2018.

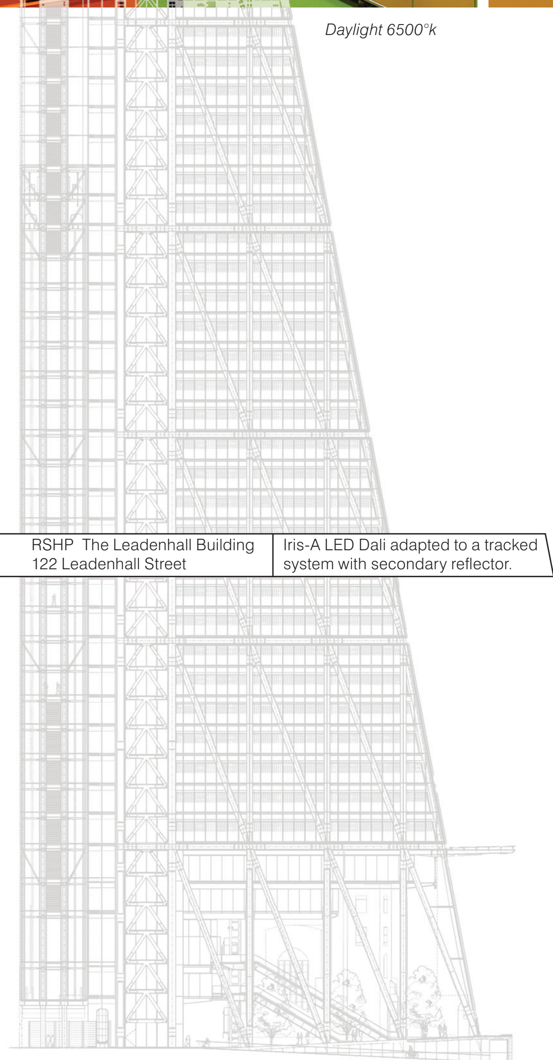
2 Ruffles, P, *SLL Lighting Handbook* - **www.youtube.com/watch?v=qZnvS3bcnA0** – accessed 10 November 2019.

Daylight 6500°k



Warm 3000°k

Neutral 4000°k



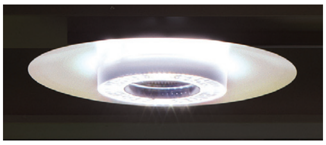
RSHP The Leadenhall Building
122 Leadenhall Street

Iris-A LED Dali adapted to a tracked system with secondary reflector.

Iris

We got rhythm. You call the tune.

Working in conformity with our natural circadian rhythm helps us remain alert and stay on top form for longer.



This LED Iris luminaire can be tuned to maintain an optimum colour temperature and level of lighting, allowing for the constantly changing quality of light throughout the working day.

We collaborated with RSHP, designers of the world famous Leadenhall Building, to adapt Iris and brighten their own 14th floor offices, by incorporating a unique aluminium dish, while retaining its trademark, multi-faceted diffuser.

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