

110 JUN/JUL 2019  
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LIGHTING IN ARCHITECTURE

# Premier League

The remarkable new  
Tottenham Hotspur Stadium  
shines in London





Front cover: Tottenham Hotspur Stadium, UK  
Pic: Getty Images, courtesy of Tottenham Hotspur Football & Athletic Co.

**Editorial**

Publisher / Editor  
**Paul James**  
p.james@mondiale.co.uk

Assistant Editor  
**Matt Waring**  
m.waring@mondiale.co.uk

Editorial Assistant  
**Sarah Cullen**  
s.cullen@mondiale.co.uk

**Advertising**

International Media Manager  
**Jason Pennington**  
j.pennington@mondiale.co.uk

International Media Sales  
**Andy White**  
andy.w@mondiale.co.uk

**Subscriptions / Marketing**

**Moses Naeem**  
m.naeem@mondiale.co.uk

**Production**

**David Bell**  
d.bell@mondiale.co.uk

**Mel Robinson**  
m.robinson@mondiale.co.uk

**Zoe Willcox**  
z.willcox@mondiale.co.uk

**Chairman**

**Damian Walsh**  
d.walsh@mondiale.co.uk

**Finance Director**

**Amanda Giles**  
a.giles@mondiale.co.uk

**Credit Control**

**Lynette Levi**  
l.levi@mondiale.co.uk

[d]arc media  
Strawberry Studios, Watson Square  
Stockport SK1 3AZ, United Kingdom  
T: +44 (0)161 476 8350  
www.arc-magazine.com  
arc@mondiale.co.uk

Printed by Buxton Press

Annual Subscription rates:  
United Kingdom £30.00  
Europe £50.00  
ROW £65.00

To subscribe visit www.arc-magazine.com  
or call +44 (0)161 476 5580

arc, ISSN 17535875, is published  
bi-monthly by Mondiale Publishing,  
Strawberry Studios, Watson Square,  
Stockport, Cheshire, SK1 3AZ.

Subscription records are maintained  
at Strawberry Studios, Watson Square,  
Stockport, Cheshire, SK1 3AZ.

Spatial Ltd is acting as our mailing agent.

# The green, green grass... of home (or the office) is becoming ever more important in lighting design...

A recent study has revealed that a two-hour dose of nature a week significantly boosts health and wellbeing even if you simply sit and enjoy the peace. The research, published in the journal *Scientific Reports* using data from a Natural England survey, is based on interviews with 20,000 people in England about their activity in the previous week. Of those who spent little or no time in nature, a quarter reported poor health and almost half said they were not satisfied with their life, a standard measure of wellbeing. In contrast, just one-seventh of those who spent at least two hours in nature said their health was poor, while a third were not satisfied with their life. The physical and mental health benefits of time spent in parks, forests or the beach are well known but for many of us living in urban areas, this is not a possibility – certainly during the working week. So how can we, as the lighting industry, help?

As Karolina Zielinska states in her article on page 49, *Biophilic Design: A Trend Watch*, millions of people spend more than 90 percent of their day in enclosed spaces and typically work a five-day, 40-hour week. It's of utmost importance to create harmonious and sustainable interior spaces to support human biology and respect plant life.

Biophilic design creates healthier spaces that support wellbeing, boost creativity, increase productivity and reduce staff absence. Adding green areas to the built environment also reduces indoor air pollution. Of course, we know that daylight is the best form of illumination for humans and plants alike. But when daylight in indoor spaces is not possible, then artificial illumination is vital. However, there is very little research and no established standards regarding this important topic. So much so that it is often left to individual lighting design practices to do their own research for individual projects (something that Julia Hartmann at lightsphere explains on page 57).

Obviously, this is not an ideal situation so we shall be tackling this subject at [d]arc room in London in September ([www.darcroom.com](http://www.darcroom.com)) with a discussion dedicated to the importance and requirements of biophilic lighting. Details and registration options will be published shortly so keep an eye out for further announcements. ■

**Paul James**  
Editor

# Biophilic Design: A Trend Watch

Having recently collaborated with Julia Hartmann and Carla Sigillo of Lightsphere on a research paper dedicated to the subject, Asst. Prof. Dr. Karolina M. Zielinska-Dabkowska IALD, IES, CIE, MSLL, RIBA, looks at the role that lighting plays in biophilic design.



Figure 1 Biophilic office with green potted plants – appropriate illumination for plants is often overlooked  
Pic: © Shutterstock/Okrasyuk

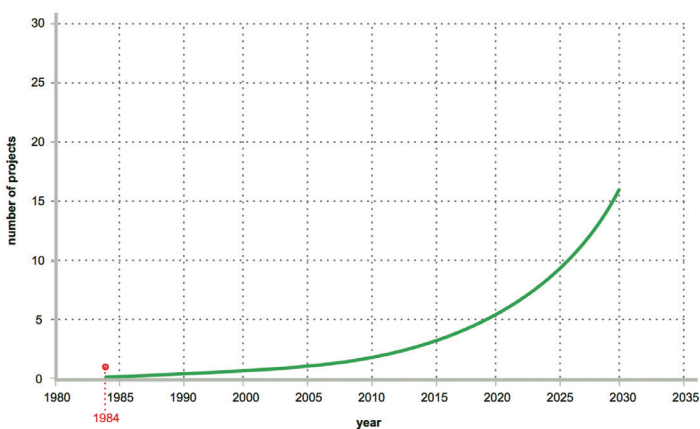
**D**uring the 20th century, many people migrated to cities for employment and economic opportunities, abandoning farming and natural landscapes so their direct connection to the countryside and nature was lost. This process continues to this day with unprecedented urban growth, in fact, it's estimated 68% of the world population will live in urban areas by 2050. Due to the evolutionary disposition of humans, when people live in an urban habitat they will still seek to restore their lost relationship with plants and the natural world. In 1994, Edward O. Wilson introduced the term *Biophilia* for the first time, which describes the deep affiliation humans have with other life forms and nature as a whole: a connection rooted in human biology. Later, at the turn of the 21st century, this knowledge began to be applied, and a noticeable global trend developed in the application of biophilic design principles in the projects of numerous, internationally recognised architectural practices (Figure 2). This included WOHA, Foster and Partners, UNStudio, BIG Architects and MVRDV to name a few. Asia and especially Singapore are still at the forefront of this new development (Figure 3).

## Sustainable Biophilic Design - Green Building Standards and Certification Systems

It has recently been acknowledged that a crucial factor of biophilia has been overlooked in the development of the 1990s green building rating and certification systems. Such schemes are voluntary and usually involve third party-assessed rating systems that relate to the built environment with the purpose of mitigating the impact of a building on the natural environment.

This is most often achieved via the integration of sustainable design, adopted by companies to demonstrate the integrity, responsibility and awareness of their organisations. The human need to connect with nature and the relationship that exists with the man-made environment goes beyond the fundamentals of low impact design with raw materials, energy efficiency, safety or pollution. Rather, it deals with the effects on the physical and mental health and wellbeing of a building's occupants. Biophilic design applies especially to office buildings. In Europe alone, millions of people spend more than 90 percent of their day in enclosed spaces and they typically work a five-day, 40-hour week. Therefore, it's of utmost importance to create harmonious and sustainable interior spaces

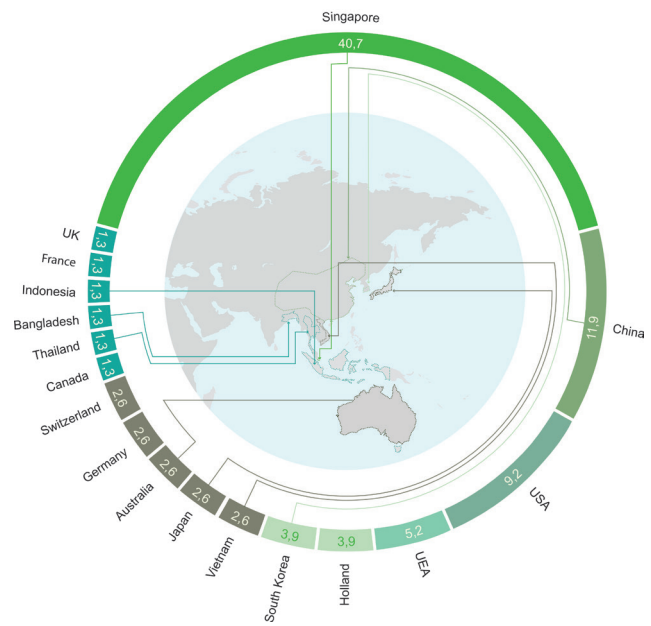
that support human biology and respect plant life. According to research, biophilic design creates healthier spaces that support wellbeing, boost creativity and focus, increase productivity, and reduce staff absence. Another factor that plays an important role in the provision of green areas and plants into the built environment is to provide cleaner air to reduce the problem of indoor air pollution. So, to bridge this gap, the introduction of biophilic design into the verification process of building design as a practical and creative solution will help to re-establish conviviality with nature in the built environment. There are three green building rating and certification systems that set benchmarks for health-centered practice that incorporate biophilic design principles: (1) the international BRE Global's Building Research Establishment Environmental Assessment Method (BREEAM), (2) the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) programme, and (3) the International WELL Building Institute's WELL Building Standard - the first performance-based building standard and certification programme to focus exclusively on the health and wellness of the people in buildings.



**Figure 2** The global trend in realized and upcoming biophilia projects in the built environment. (Data has been estimated from projects on the websites of internationally recognised architectural practices starting from the year 1984, and from the publication of the book *Biophilia* by Edward O. Wilson.) © K.M. Zielinska-Dabkowska & J. Hartmann

In the BREEAM UK New Construction 2018 Land Use and Ecology (*LE 04 Change and enhancement of ecological value category*) <https://bit.ly/2Wkpv4Y>, credits can be achieved by improving the health, wellbeing and potentially, the productivity of occupants, users and neighbours through the provision of recreational space and an increased connection between people and the natural environment (biophilia). The intention of LEED v.4 for the New Constructions Credit called *Designing with Nature, Biophilic Design for the Indoor Environment* is to support and improve human health, wellbeing, and productivity by providing and incorporating elements of nature in the indoor environment (<https://bit.ly/2WgirGJ>). A biophilic design plan incorporates at least five distinct design criteria related to biophilic design which must be developed and implemented. This includes: providing regular access to nature in the space, offering natural analogues, ensuring spatial properties align with the nature of the space, uniquely connecting people to the place, climate, and culture, and lastly, creating sufficient opportunities for human-nature interactions within the building and within the project boundary, external to the building. In the WELL v2 pilot (<https://bit.ly/2wzi7U8>), the new version of WELL Building Standard, one can achieve credit points in Feature 89 Biophilia I - Qualitative by presenting a biophilia plan that includes a description of how the project incorporates nature through the environmental elements, lighting and space layout (<https://bit.ly/2ljsdhk>). Additionally, two requirements in Feature 100 Biophilia II - Quantitative for Indoor Biophilia have been established: potted plants or planted beds should cover at least one percent of floor area per floor and/or a plant wall

per floor, covering a wall area equal to or greater than two percent of the floor area, or covering the largest of the available walls, whichever is greater (<https://bit.ly/2EOw4SK>). Achieved BREEAM credits and criteria may contribute to claiming WELL certification. Although biophilic design goals might sometimes conflict with the most energy-efficient design requirements, a fully sustainable building must meet the needs of its occupants.



**Figure 3** A worldwide comparison of estimated biophilia projects by country, showing Singapore as a leader in this initiative. © K.M. Zielinska-Dabkowska & J. Hartmann

## Biophilic Design and Lighting - A Field In Flux

With recently published reports such as *HUMAN SPACES: The Global Impact of Biophilic Design in the Workplace*, books (<https://bit.ly/2wtT4lx>, <https://bit.ly/2WFM1F4>), past and upcoming conferences and seminars (<https://bit.ly/2HOvC8N>, <https://bit.ly/2VRjpEw>) clients and architects expect their projects will incorporate these new elements. Interestingly, when consulting lighting manufacturers or plant specialists on how to illuminate ornamental plants for real life projects with LEDs, often answers aren't available because there are no worldwide established standards and recommendations regarding how to correctly illuminate them. Furthermore, if there is no daylight available in built environments, many plants do not survive so they need to be constantly replaced due to insufficiently designed and specified artificial lighting. Therefore, the recently published study in *Sustainability Journal* called *LED Light Sources and Their Complex Set-Up for Visually and Biologically Effective Illumination for Ornamental Indoor Plants* (<https://bit.ly/2QHE24P>) might be an interesting read for those who are looking for specific answers on the subject. This research work has been inspired by the need to provide appropriate ornamental plant illumination for the Zurich Innovation Center Givaudan, Kempththal - a real life project (<https://bit.ly/2JTPZDQ>). A master thesis was developed, which translated the vision of the Givaudan project into the academic field (<https://bit.ly/2lip1Cz>). This thesis formed a research-based foundation, and its findings instigated further detailed study, as presented in the research paper. This research shows the complexity that's involved in designing illumination for people and plants in indoor spaces, and attempts to answer the question for an optimal action spectrum for visually and biologically effective LED illumination. Additionally, the authors create sustainable design principles when applying LEDs to provide illumination for ornamental plants indoors.

Table 1. Different requirements for illumination between ornamental plants and humans  
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Exposure Variable	Plants	Humans
UV-A	Required	Avoided due to ageing, skin burns, skin cancer
UB-B	Required	Required for vitamin D synthesis
Full spectrum visible light	Required for photosynthesis	Required for vision and overall health and wellbeing (resetting of circadian rhythms for hormonal activity, jet lag and Seasonal Affective Disorder adjustment)
Blue light (peak 460nm)	Required	Avoided at night due to melatonin suppression
NIR/IR	Required	Required but with controlled exposure to avoid skin burns, cataracts
Intensity of light energy (PPFD/Lux)	Required for photosynthesis	Required for vision
Appropriate timing of light	Required	Required to avoid exposure of specific wavelengths of light in the evening and at night
Appropriate light duration (24h photoperiod - diurnal exposure to daylight and darkness)	Ca. 14h light exposure (depending on species and geographical location) followed by 10h of darkness	Ca. 16h light exposure (depending on season and geographical location) followed by ca. 8h of darkness

As listed in Table 1, we can see that there are crucial light-related requirements such as the light spectrum, the intensity of light energy as well as the timing and duration of light, which affect both ornamental plants and humans.

Light information about the environment has been both intercepted by plants and humans via different photoreceptors containing certain photosensitive pigments that absorb electromagnetic radiation at a specific wavelength (Figure 4).

Green plants react to optical radiation they use for photosynthesis (transforming light energy into chemical energy) as well as photomorphogenesis (for overall development control as well as defining their shape).

The action spectrum for plants, known as the *McCree Curve*, has been defined between 280–800nm, and the part beyond the visible light spectrum is shown as a continuous black line on the drawing. The *Photosynthetically Active Radiations (PAR)* spectral range, commonly used in horticulture, contains an incomplete range between 400–700nm for whole plant development, shown as a dashed box on the drawing. Research clearly states, that the photomorphogenesis of various plants require the electromagnetic radiation outside the PAR range from ca. 380–850nm and any exclusion of specific wavelengths such as UV light and far-red will have an impact on other plant processes, which will in consequence, have a negative impact on growth and development.

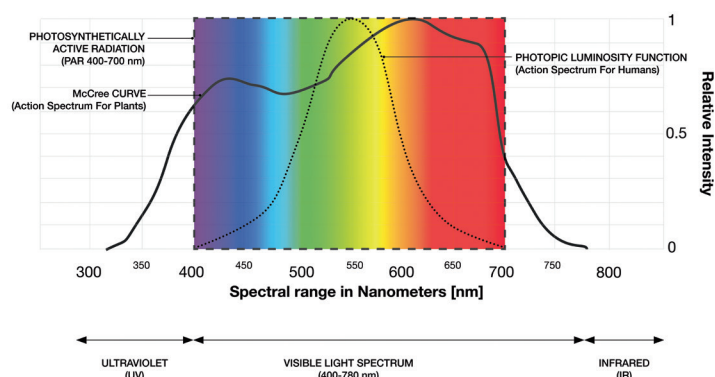


Figure 4 A comparison of action spectra for plants' photosynthesis and human's visual perception. Infrared and UV values based on International Commission on Illumination (2009).  
© K.M. Zielinska-Dabkowska, J. Hartmann & C. Sigillo

Whereas, the action spectrum for humans is determined by the luminosity function  $V(\lambda)$ , shown as a dotted line on the drawing and a range between 380–760nm. So we not only have different light

related requirements between plants and humans, but also there is an issue of standard measuring devices that only include visible light ranges based on CIE recommended spectral luminous efficiency functions. Lastly, standard LEDs as non-thermal light sources do not produce advantageous thermal IR wavelengths of light, which is beneficial for plants as well as humans.

## Conclusions

The following conclusions driven from this study can be summed up in the points below:

- Daylight in indoor spaces is a preferred form of illumination for ornamental plants, due to its broader, continues spectrum.
- When daylight levels are insufficient, artificial illumination should always attempt to replicate how ornamental plants appear in daylight. (This is based on a deeply engraved evolutionary relationship with natural light, where humans will always have a preference for the daylight appearance of plants in interior settings compared to artificial illumination).
- Architectural white LED lighting with the standard CCT metric applied for indoor spaces cannot provide visually and biologically effective illumination for ornamental indoor plants alone.
- The coloured, artificial illumination used for growing horticulture food plants should not be applied to indoor environments, as it gives an unnatural appearance to indoor ornamental plants and it lacks the healthy properties of full spectrum light required by humans and plants.
- The right action spectrum for biologically effective illumination for ornamental indoor plants can be generated with correctly designed LED light sources (specific wavelengths and their spectral ratio) as well as lighting control.
- When designed correctly, biologically effective LED illumination for ornamental indoor plants can also look natural and visually appealing.
- There is a lack of proper research methodology for ornamental indoor plants to base this research on, such as establishing and evaluating the optimal wavelength selection and spectral ratios of LED light sources.
- The detected/recorded wavelength range of universal measuring devices is limited and excludes non-visual light below 380 nm and above 760 nm. ■



Asst. Prof. Dr. Karolina M. Zielinska-Dabkowska is a chartered RIBA architect and award-winning practicing lighting designer. She is also an Assistant Professor at the Faculty of Architecture, Gdansk University of Technology, Poland, and co-founder of GUT LightLab, where she conducts research on various aspects of light and lighting in the built environment. She is actively engaged in the work of international organisations such as the International Association of Lighting Designers (IALD), the Illuminating Engineering Society (IES), and International Dark-Sky Association (IDA), providing guidelines and sharing best practice for nighttime illumination in the built and natural environment. She has participated in a number of international conferences, and has written articles for national and international publications. Karolina joined Woman In Lighting (WIL) in March 2018 as an Ambassador for Poland.