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Overview of Industry Research on LED Lighting Technology and Application to the Federal Sector

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OVERVIEW OF INDUSTRY RESEARCH ON LED LIGHTING TECHNOLOGY AND APPLICATION TO THE FEDERAL SECTOR

The Federal Energy Management Program (FEMP), in partnership with the General Services Administration (GSA), is currently investigating how traditional building energy-efficiency measures can impact health in the federal sector through the Healthy Buildings Toolkit.

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Background

Based on initial results of healthy buildings pilot projects in partnership with the General Service Administration, FEMP decided to explore in depth the existing research on the use of light-emitting diodes (LEDs), looking specifically at industry claims regarding the benefits of LEDs for human health and comfort. LEDs for general lighting or "white" LED lighting (which emits significantly less red and near-infrared radiation, 360–780 nm) is quickly gaining popularity by federal agencies and energy managers. Between 2016 and 2018, installed indoor lighting penetration doubled from 14.6% to 29.8%, and is expected to be the dominant domestic and public light source in use by 2030 (Elliott 2020; ICNRP 2020). Thus, it is important to consider the impacts of this technology on occupants. Beyond the safety and task performance aspects of providing enough illumination (quality and quantity of light) to properly see, lighting effects the health and comfort of people in buildings in other important ways. Presented are four major occupant benefits highlighted by the lighting industry: increased worker productivity, improved quality of sleep, reduction in eye strain and headaches, and the non-toxicity of LEDs.

Increased Worker Productivity and Cognitive Performance

Several companies (e.g., Eaton n.d., LightCorp n.d., MAC Electric, Philips 2014, Safelumin 2019) highlight the benefits of LED lighting on worker productivity. Amerlux, an LED manufacturer, points to studies that have found improvements in worker cognitive function and productivity from using LED lighting (Amerlux, n.d.). Another company, Eaton, links the health benefits of LED lighting with company or building brand image. Eaton suggests that building standards that include provisions on the air quality, thermal conditions, lighting quality, and other health and wellness aspects, such as the Leadership in Energy and Environmental Design (LEED) and WELL, improve workers' perception of their space.

The metrics typically used for productivity are based on satisfaction and opinion surveys of the employees. For instance, in 2019, LEDs Magazine cited a survey conducted by a UK online retailer of solid-state lighting (SSL) which reported that 77% of respondents felt that lighting in the workplace can affect their productivity and 32% respondents would be happy to work under electric light that is designed to aid productivity (Halper 2019). The company Senior LED (2018) suggests that because LEDs do not make a buzzing sound, employees are able to concentrate better and there are less workflow disruptions.

According to an article by Signify (formerly Philips), one example of how LEDs can enhance productivity in the workplace is by reducing the glare resulting from poor lighting. In a pilot study they conducted at a Bosch office, the company installed recessed LED luminaires with daylighting controls (Philips 2014). In their study, they found that the lighting systems reduced electricity consumption by 52% and that with optimum use of the daylight and occupancy sensors, energy savings of up to 72% could be expected. They did not provide

quantitative results for the impact on workers' productivity but did suggest that because LEDs with controls can reduce glare, they aid in employee concentration.

According to Eaton (n.d.) and Mac Electric and Lighting (n.d.), LEDs can also enhance learning performance. For example, Eaton suggests that by tuning LEDs with proper illuminance levels and color temperature, LED lights support cognitive performance in educational settings. In addition, Eaton notes that when compared to conventional lighting technology, modern LEDs produce less heat, which reduces HVAC energy use, and requires fewer lighting fixtures for the same light output.

Improved Quality of Sleep

Similar to worker's productivity, improved quality of sleep is cited as a benefit of enhanced lighting. Chronic sleep loss can result in various health issues, such as weakened memory, slowed metabolism, increased irritability and moodiness, hypertension, and a weakened immune system. Companies such as General Electric (2014) claim to engineer LED lamps to provide individuals with the appropriate illumination conditions they need throughout the day in order to suppress melatonin, the "sleep hormone", which can help employees maintain their natural sleep cycles. According to Eaton (n.d.), recent developments in LED technology allow LEDs to mimic the stimulus provided by daylight, which promotes a healthy and regular circadian rhythm. When there is not enough sunlight available in a building, exposure to color-tuned LED light at targeted blue wavelengths (400-525 nm) for a limited duration during the early day can be an effective substitute. Similarly, exposure to "warm" light, which has less blue and more red-light wavelengths, in the evenings can provide sufficient illuminance without significantly suppressing melatonin to help people prepare to fall asleep (Eaton n.d.). Thus, the transition to warm lighting in the evening promotes a healthy sleep pattern.

Reduction in Eye Strain and Headaches

Companies such as Safelumin (2019) and Eaton (n.d.) claim that LEDs benefit occupants because they do not flicker, or flicker less than other lighting types. Traditional fluorescent bulbs that flicker, especially ones with magnetic ballasts, can result in negative effects for those who suffer from migraines and headaches. Companies, such as Eaton, recommend pairing LEDs with lighting controls to provide occupants the ability to customize and set individual light levels that improve comfort and address light sensitivity.

LEDs Are Non-toxic

Another benefit of LEDs according to Senior LED (2018) and LightCorp (n.d.) is that LEDs are manufactured with no hazardous materials such as mercury, which is commonly found in incandescent and fluorescent bulbs. This benefit has been scientifically supported (Ticleanu and Littlefair 2015). The WELL Building Standard has a credit for providing lighting without mercury, which is a prerequisite for all WELL-certified projects.[1] Senior LED (2018) and LightCorp (n.d.) also note that the ultraviolet (UV) rays produced by LED light are negligible or non-existent, thus making them safe to use in close proximity to occupants, such as on a desktop. LEDs that do produce UV light are being sold for other purposes, such as disinfecting supply air.

Key Considerations

When comparing the reported benefits against the existing scientific evidence on lighting, it is important for all federal agencies and energy managers to note that there remains little consensus regarding the effects of LEDs on occupant health and comfort. The impact of LEDs is highly dependent on their spectral, optical, and electrical characteristics, as well as the physical properties of the lamps using the technology (ANSES 2020, Ticleanu and Littlefair 2015). Research on the effects of lighting on melatonin and circadian rhythms is ongoing. Furthermore, applying this research to lighting design is challenging and some view it as premature (Ashdown 2019).

[1] Information on this credit can be found at: https://v2.wellcertified.com/wellv2/en/materials/feature/1

The light spectra emitted by LEDs can have more blue content and less red content, or vice-versa, depending on the phosphors used. Some research suggests that intense exposure to “blue light” (high color temperature) LEDs may lead to eye damage and natural sleep disturbances (ICNIRP 2020), but other research points out that light sources such as daylight and incandescent lamps at the same color temperature have the same or more blue light than LEDs, and that the color temperature and light output typically found in buildings is not extreme enough to be of concern (U.S. DOE 2014).

LEDs, like all electric light sources, exhibit flickering; however, most LEDs have built-in immunity, unlike incandescent fixtures, which reduces the perception of flickering during voltage fluctuation tests (Gaines 2019). According to the ICNIRP, even if the light from LEDs does not produce a visible perception of flickering, a portion of the population can still experience headaches, migraine, and other adverse effects (ICNIRP 2020). The neurological effects of LEDs are not yet fully understood.

This emerging research underscores the need for federal agencies and managers to consider not just how LEDs compare to traditional lighting sources, but also its effects on occupant health in the context of its intended application. This includes consideration for duration of exposure, illuminance level, and spectral characteristics.

References

[1]Amerlux (n.d.) How LED Lighting Increases Employee Productivity and ROI. https://blog.amerlux.com/how-led-lighting-increases-employee-productivity-and-roi/.

[2]ANSES (Agence Nationale de Sécurité et Sanitaire) 2020. LEDs & blue light: Health effects of lighting systems using light-emitting diodes (LEDs). https://www.anses.fr/en/content/leds-blue-light.

[3]Ashdown, I (2019). Circadian Lighting: An Engineer's Perspective. Illuminating Engineering Society. https://www.ies.org/fires/circadian-lighting-an-engineers-perspective/.

[4]Eaton (n.d.) 4 major health benefits of LED lighting. https://www.eaton.com/us/en-us/company/news-insights/lighting-resource/trends/4-major-health-benefits-of-led-lighting.html.

[5]Elliott, C and Lee, K (2020). Adoption of Light-emitting Diodes in Common Lighting Applications. Prepared by Guidehouse, Inc. for the U.S. Department of Energy. https://www.energy.gov/sites/prod/files/2020/09/f78/ssl-led-adoption-aug2020.pdf.

[6]Gaines, J (2019). Concerns in the Age of the LED: Temporal Light Artifacts. Illuminating Engineering Society. https://www.ies.org/fires/concerns-in-the-age-of-the-led-temporal-light-artifacts/.

[7]Halper, M (2019). Employees say lighting affects their productivity. LEDs Magazine. https://www.ledsmagazine.com/manufacturing-services-testing/substrates-wafers/article/16699064/employees-say-lighting-affects-their-productivity.

[8]ICNIRP (International Commission on Non-Ionizing Radiation Protection). (2020). Light-Emitting Diodes (LEDS): Implications for Safety. Health Physics, 118(5), 549-561.

[9]LightCorp. 5 Ways LED Lighting Can Benefit Your Health. https://www.lightcorp.com/files/resources/Health_benefits_of_LED_light.pdf.

[10]MAC Electric and Lighting (n.d.) Five Health Benefits of LED Lighting. https://macelectricco.com/five-health-benefits-led-lighting/#:~:text=Balances%20Circadian%20Rhythm,seem%20to%20do%20the%20trick.

[11]Philips (2014) Case Study Bosch. Philips. https://images.philips.com/is/content/PhilipsConsumer/CaseStudies/CSLI20141119_013-ECT-global-bosch-offices.pdf.

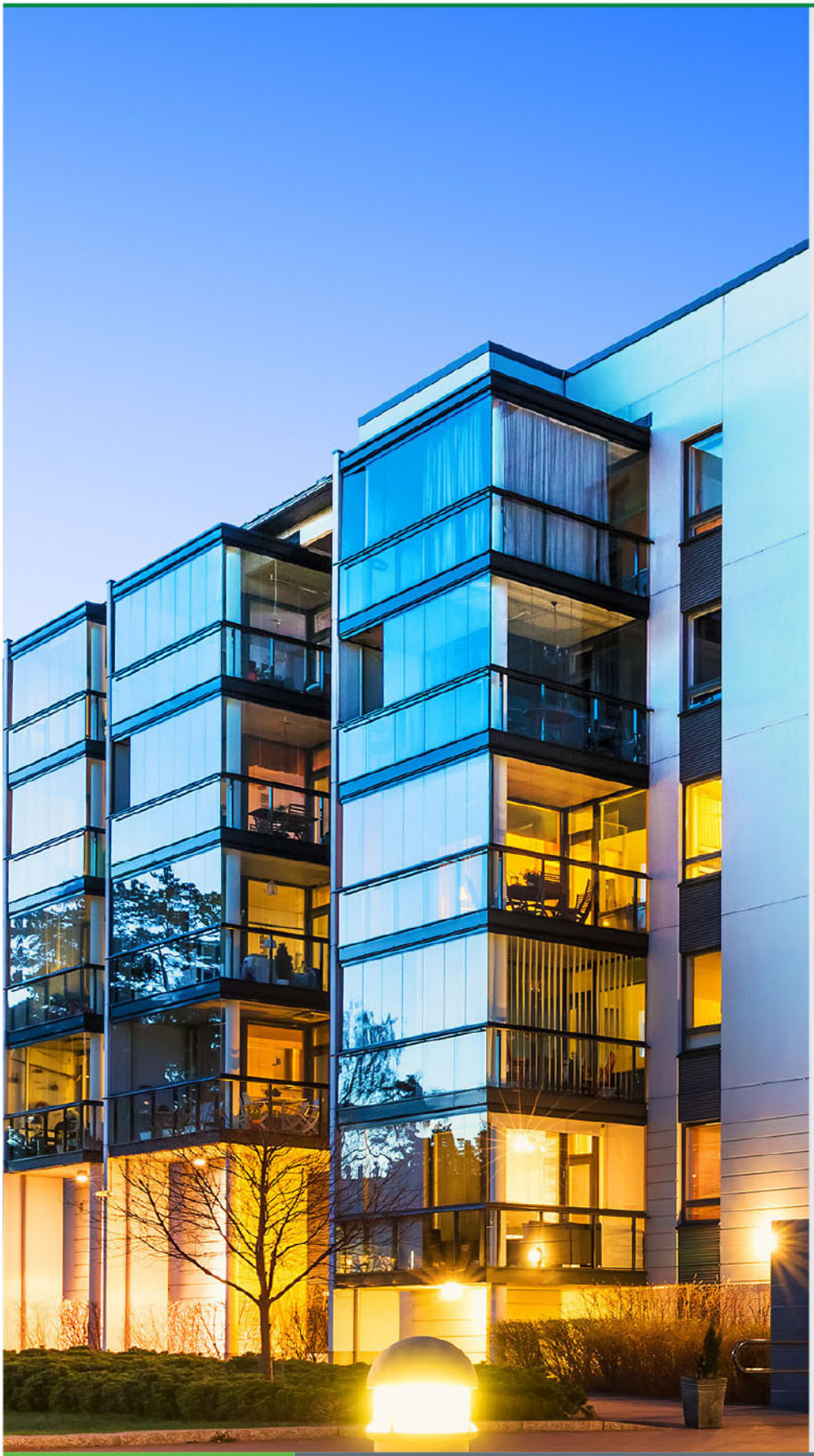
[12]Romm, J. J., & Browning, W. D. (1994). Greening the building and the bottom line. Rocky Mountain Institute. Snowmass, Colorado.

[13]Safelumin (2019). 4 Major Health Benefits of LED Lighting. https://safelumin.com/4-major-health-benefits-of-led-lighting/.

[14]Senior LED (2018). 10 Amazing Benefits of LED Lighting in Offices & Workplaces. https://www.seniorled.com/benefits-led-lighting-offices/?cn-reloaded=1.

[15]Ticleanu, C., & Littlefair, P. (2015). A summary of LED lighting impacts on health. International Journal of Sustainable Lighting, 17, 5-11.

[16]U.S. DOE (U.S. Department of Energy). (2014). True Colors. U.S. Department of Energy Building Technologies Office. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/true-colors.pdf.



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