



READY, OR NOT?

We know that lighting has the power to significantly affect human health, performance and well-being. But do we know enough today to apply this knowledge wisely in our healthcare facilities?



OVERVIEW

The lighting industry has enthusiastically moved ahead with human-centric lighting solutions tailored to healthcare providers. Some intend to reap the benefits of maintaining people’s natural circadian cycles, helping improve the sleep, mood and biological responses of patients and families. Others employ lighting strategies to boost the alertness, energy and performance of caregivers and facility staff.

The argument for embracing these solutions right now is pragmatic: today, virtually every patient – from premature newborns in PICUs to seniors in long-term care facilities – live, sleep and convalesce under inflexible lighting. Their caretakers – doctors, nurses and other staff – work day and night under the same lighting. Like all illumination, these lights have a myriad of effects on human physiology. If a hospital, clinic or long-term care facility is preparing to install new lighting, shouldn’t they use what is known to maximize lighting’s beneficial effects, or at the very least, minimize any downsides? And won’t healthcare providers that choose non-adaptive lighting risk falling behind those that leverage more advanced lighting solutions?

The counterargument is one of prudence: our knowledge is incomplete, and healthcare providers should wait for more evidence before investing in human-centric lighting. One concern is that some of the indicated benefits have yet to be confirmed by large, rigorous, replicable longitudinal studies across various age groups and circumstances. While much is known and readily applied about the optimal visual characteristics of lighting for different cohorts, nonvisual physiological and psychological effects are less well understood.

Those in favor of investing sooner rather than later also point out that a number of highly respected industry organizations have developed well-researched application guidelines and metrics to enable adoption right now based on what is known.

With all that in mind, we’ll help healthcare administrators, design professionals and facilities managers sort through the evidence and anecdotes, facts and opinions to reach an informed answer to the central question of human-centric lighting: Act now – or wait and see?



Mental Alertness



Increased Energy



Overall Performance

What We Know

For millions of years, humans woke up, lived, learned and thrived outdoors under the reliable and natural movement of the sun. We thus evolved our circadian cycle – a biological clock exquisitely calibrated to align our physiology to the different phases of a 24-hour day.

But in modern society, people spend over 90 percent of their time indoors, far from natural sunlight. We typically experience too little light in the day and too much at night. Some of the effects created by this mismatch of ambient lighting and our internal clock have long been known. Jet lag is one of the most profound, common and dreaded examples. Crossing multiple time zones (especially moving from west to east) leaves us plagued by daytime lethargy and nighttime insomnia for several days until our internal clock resets.

In recent decades, interest in lighting's effects on humans has trended sharply upward. The advent of LED lighting only added to the impetus. The initial attractions of LED lighting were its dramatic energy savings, longer lifetimes and much lower maintenance costs. But lighting experts and researchers soon realized LED lighting's greater potential: solid-state technology made it cost-effective to develop smart lighting solutions that could be tuned to different color temperatures, automated to respond to ambient daylight, dimmed in minute increments and configured to express carefully sculpted spectral distributions.



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A New Lighting Fundamental

Sunlight was the only significant light source for 99.999% of the time that life has evolved on earth, so natural light's position as the gold standard is unlikely to change anytime soon.

But now that our industry more fully understands the profound biological, functional and emotional effects that lighting has on people, intense interest in the science of lighting is revealing exciting new ways to use the next best thing: artificial lighting that emulates the spectral properties of natural light and the 24-hour cycle of day and night.

Three scientists won the 2017 Nobel Prize in Physiology or Medicine for work uncovering the molecular mechanisms controlling our circadian clock, including light's powerful role. Their work identified a nonvisual type of photoreceptor in the human eye named intrinsically photosensitive retinal ganglion cells (ipRGCs) which have a different function than rods and cones.

This confirmed decades of previous research suggesting that a circadian rhythm synchronized to natural light helps us feel more energized during the day and sleep better at night. This circadian entrainment also improves our immune system, lowers our stress and even reduces our risk for diseases like diabetes, obesity, cancer and mood disorders.



Circadian rhythm synchronized to natural light

Mariana Figueiro, former Light and Health Program Director at the Lighting Research Center (LRC), and now the Director of the Center for Healthy Aging and the Division Chief of Sleep and Circadian Medicine in the Department of Medicine at the Robert Wood Johnson Medical School, is a vocal proponent of the benefits of circadian-supportive lighting. She is author and co-author of scores of lighting research papers cited thousands of times by other investigators. In a *TEDMED* blog coinciding with the 2015 United Nation's International Year of Light, she noted that light was revolutionizing medicine, and that "light-based technologies promote sustainable development and provide solutions to global challenges in energy, education, agriculture and health.

In contrast, if our circadian rhythm is misaligned – that is, if we get too little light from the blue end of the visible spectrum during the day, or too much of it at night – a host of negative consequences can arise, including agitation, chronic fatigue, an inability to concentrate and an increased risk for various diseases.

In fact, the short (blue) wavelengths, perceived as brighter light, are not just the strongest synchronizing agent for the circadian system. They also enhance alertness and wakefulness, enabling faster reactions, fewer lapses in attention and overall better performance of complex visual tasks.

Many lighting solutions on the market now offer automated or manual tuning of correlated color temperature (CCT). This tuning changes the ratio of blue light to the rest of the visible spectrum to mimic the gradual spectral shift of daylight from morning to evening.

Benefits can include:



Lowered Stress



Improved Performance of Complex Visual Tasks



Less Fatigue



Reduced Depression



Enhanced Alertness



Increased Energy

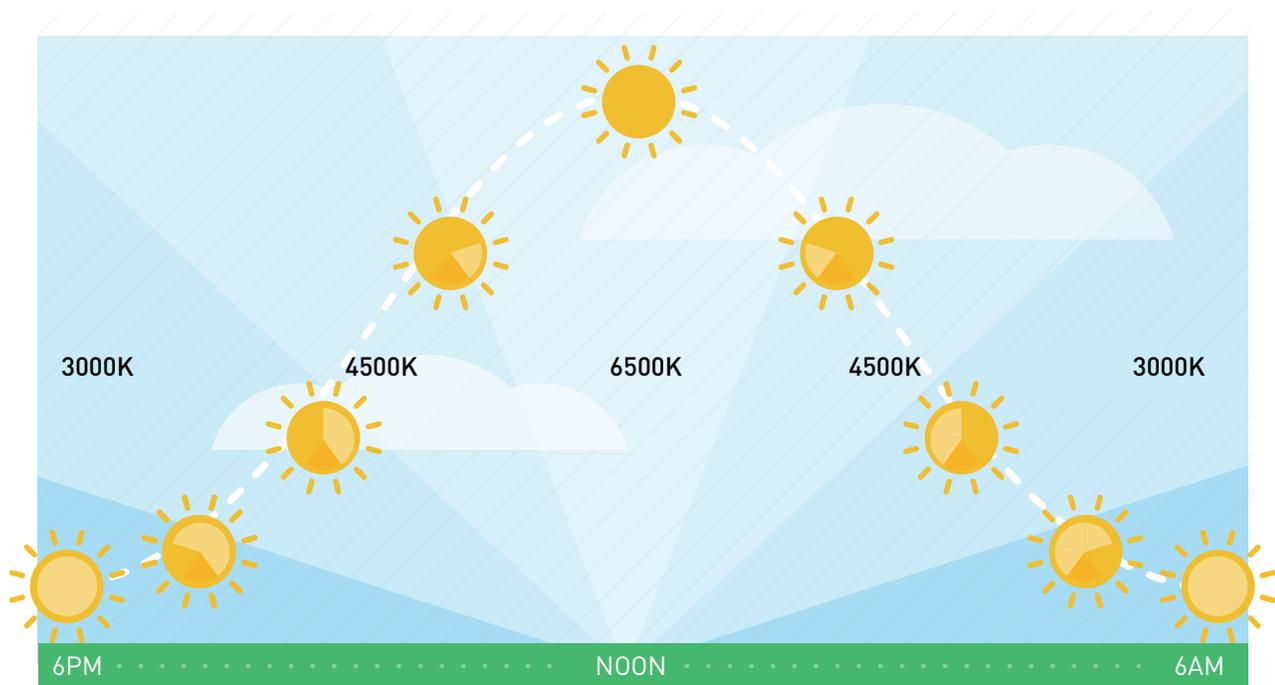


A Strengthened Immune System



Improved Sleep

But tunable CCT alone is not sufficient to fully recreate sunlight's effect on human circadian rhythms. Factors such as the intensity and duration of the light at various wavelengths, and the shift in light distribution across the day, also impact circadian entrainment. Nor is the circadian cycle the only physiological impact of lighting on humans. Factors such as glare and visual comfort must also be considered.



What This Could Mean For Healthcare

Human-centric lighting has obvious, significant implications for healthcare facilities, especially hospitals, long-term care and assisted living facilities where patients spend days, weeks or months primarily indoors. Around the globe, medical researchers and care facilities are conducting pilot programs and further research to assess and confirm the benefits of lighting interventions.

To date, the preponderance of evidence indicates that exposure to circadian-tuned lighting does confer general benefits such as improved alertness, energy levels and mood support for patients, providers and administrators. Nor do these gains go unnoticed – the evidence also suggests such lighting improves patient, visitor and staff satisfaction, and increases quality rankings and scores. Studies have noted that patients in sunny rooms have shorter hospital stays than patients in dark rooms, and researchers are now investigating whether this benefit extends to lighting designed to mimic daylight.^{1,2}

For nursing homes and assisted living facilities, lighting intervention tailored to maximally entrain the circadian system has been shown to significantly improve sleep quality, depressive symptoms and agitation behavior in



patients with Alzheimer’s and dementia. Furthermore, it can have a positive effect on metrics as diverse as patient falls, pharmacy errors and caregiver absenteeism.

What may be the most exciting questions have yet to be definitively answered: Does human-centric lighting directly improve patient outcomes? What about medical staff performance?

The evidence is insufficient to unequivocally make these claims. But ongoing research findings and anecdotal reporting on pilot programs are promising.

A Department of Energy (DOE) report cited that target behaviors such as yelling, agitation and crying were reduced by an average of 41% for senior patients participating in a trial installation of LED lighting systems within the ACC Care Center in Sacramento, CA.³

A Mount Sinai Hospital pilot to improve the lighting for stem-cell transplant patients demonstrated “very positive” effects on depression, fatigue and sleep quality.⁴

Circadian-supportive lighting installed in the Specialist Medical Behavioral Unit at the Children’s Hospital of Philadelphia, which treats children with medical problems who also have underlying behavioral conditions such as depression, anxiety and autism, was anecdotally reported to be very popular with staff and patients.⁵

Automatic circadian lighting that changes from early morning to late night is part of post-stroke patient care at the Central Hospital in Karlstad, Sweden.⁶

¹ [Dying in the dark: sunshine, gender and outcomes in myocardial infarction](#); J R Soc Med. 1998 Jul;91(7):352-4.

² [Morning sunlight reduces length of hospitalization in bipolar depression](#); J Affect Disord. 2001 Feb;62(3):221-3.

³ [Tuning the Light in Senior Care: evaluating a Trial LED Lighting System at the ACC Care Center in Sacramento, CA](#); U.S. Department of Energy website, August 2016

⁴ [Treating Cancer-Related Fatigue Through Systematic Light Exposure \(Light for Fatigue Study\)](#); ClinicalTrials.gov Identifier: NCT03119363

⁵ [The era of circadian lighting in health care is dawning](#); Stacey Burling, The Philadelphia Inquirer, June 27, 2018

⁶ [Shine a Healing Light: Circadian-Based Lighting in Hospitals](#); Kristin Jenkins, MEDSCAPE, February 28, 2018

Numerous studies have verified that coordinating the lighting in the patient environment to mimic a day-night cycle helps maintain the natural circadian cycle vital to an effective preventive program to forestall delirium, reduce inflammatory response and promote better patient outcomes. Exposure to bright light in the morning hours has even been shown to help restore a disrupted circadian rhythm.^{7, 8, 9, 10}

In one study of 338 patients in medical and surgical ICUs, the introduction of an environmental noise and light reduction program designed to help mimic a consistent day-night cycle reduced the incidence of ICU delirium by 63 percent and the average duration of delirium episodes from 3.4 to 1.2 days.¹¹

Researchers at Yale University, New Haven, Connecticut, explored using circadian light to reduce delirium in patients admitted to the intensive care unit after cardiac surgery. After 14 days, patients who received light/dark-patterned light reported better sleep and reduced fatigue.¹²

Researchers at the University of Minnesota's Masonic Children's Hospital in Minneapolis launched a pilot study to assess the impact of circadian lighting systems on delirium and quality of sleep in the pediatric ICU.¹³

Employees with windows in the workplace received 173 percent more white light exposure during work hours and slept an average of 46 minutes more per night than employees who did not have the natural light exposure.¹⁴

Researchers have found that sunny hospital rooms accelerate recovery from severe depression, and that bipolar patients exposed to direct sunlight in the morning had hospital stays 3.5 days shorter than patients who were not.¹⁵

Harnessing A Complex Science

The LED lighting industry has prided itself for increasingly rigorous technical application standards and precisely calculable ROI. But it's a different kind of challenge to establish similar metrics that involve the complex systems of human physiology, or to quantify intangible benefits like "a better healthcare environment."

For example, a 2018 article published in *arc*, an international magazine in architectural lighting design, summarized a human-centric lighting workshop with industry leaders who stressed that the most energy-efficient LED lighting produces blue-rich white light similar to the bright light of midday, but has a different spectral power distribution, and therefore would have different biological effects.

Lighting scientists and related organizations are still tackling the challenge. At the same time, neuroscientists, biologists, academics and others are continuing research to answer the questions necessary for optimal application: What intensity and color of light should be applied when and where, and for how long? How much must guidelines vary by age, sex and other biological differences? Are there other important nonvisual effects (positive or negative) that we've yet to identify?

⁷ [Beyond the Ceiling: Healthy Lighting for Hospitals](#); Craig DiLouie, Electrical Contractor, May 2018

⁸ [Sleep and Circadian Rhythm in Critical Illness](#); Irene Telias and Mary Elizabeth Wilcox, *Crit Care*. 2019; 23: 82. Published online 2019 Mar 9

⁹ [Illuminating the importance of light design](#); Julie Slater, TEDMED 2014, posted on May 5, 2015

¹⁰ [Effect on nurse and patient experience: overnight use of blue-depleted illumination](#); Lorenzo Albala, et al, *BMJ Open Qual*. 2019; 8(3): e000692. Published online Sep 26, 2019

¹¹ [Prevention of ICU Delirium Through Implementation of a Sleep Promotion Bundle](#); Victoria Bennett, University of New Hampshire Bennett, Master's Thesis, 2015

¹² [Factors Influencing Patients' Sleep in the Intensive Care Unit: Patient and Clinical Staff Perceptions](#); Qinglan Ding et al, *Am J Crit Care*. 2017 Jul; 26(4): 278-286.

¹³ [Innovative Hospital Lighting System Designed To Boost Healing For Masonic Children's Hospital Patients](#); University of Minnesota Masonic Children's Hospital website, July 21, 2016

¹⁴ [Natural Light in the Workplace Increases Health](#); Marla Paul, *News, Feinberg School of Medicine*, Northwestern University, Aug 12, 2014

¹⁵ [Morning sunlight reduces length of hospitalization in bipolar depression](#); F Benedetti et al, *J Affect Disord*. 2001 Feb;62(3):221-3.



THOSE READY TO ADOPT

Whatever it's called – human-centric lighting, circadian lighting, research-informed human lighting (RIHL), experiential lighting – many experts and lighting manufacturers believe lighting that's beneficial for humans is now actionable.

Underwriters Laboratories (UL) recently published the "Design Guideline for Promoting Circadian Entrainment with Light for Day-Active People," DG 24480, based on the Circadian Stimulus (CS) method developed by Rensselaer Polytechnic Institute's Lighting Research Center (LRC). It relies on the LRC's CS Calculator, a web-based tool for converting predicted or measured vertical illuminance values into CS metric values.

The WELL Building Institute has also added circadian-supportive lighting to its recommendations with a spectrum component weighted to these ipRGCs called the Equivalent Melanopic Lux (EML). Other potential metrics are now emerging, including a circadian action factor, melanopic sensitivity and melatonin suppression index.

While these competing models and metrics don't completely overlap, all support the idea that lighting is a main contributor to our circadian systems and that our built environment can play a larger role.

That's fortunate, as interest continues to surge. LEDs Magazine's 2020 State of the Industry Survey reported that lighting for health and wellbeing outscored other niche applications in terms of respondent interest.



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THOSE WHO BEG TO DIFFER

Proposed models like the CS and EML are most troubling to critics because of the complexity and diversity of how light affects human biology.

Human differences are vast, and factors that could influence our response to lighting beyond alignment with a standardized circadian clock vary tremendously. These factors include not just who we are biologically (age, gender), but where we are, what we've been doing, and other independent behavioral and environmental factors.

In a 2019 paper published by the IES called *Circadian Lighting: An Engineer's Perspective*, Ian Ashdown, a retired senior scientist at SunTracker Technologies, detailed the technical shortcomings of both the CS and EML metrics. He finally asserts that "Regardless of what we may know about the effects of circadian lighting on human health and wellbeing, we may never be able to codify this knowledge in building design practices."

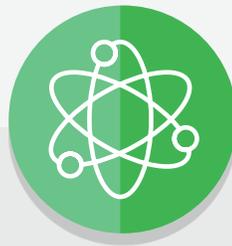
Other detractors are less pessimistic. But many are still concerned both with the complexity of the science and whether the industry is overreaching in its claims, especially since investigators are still wrestling with how best to quantify them.

In her 2018 article *Age of Enlightenment: The Promise of Circadian Lighting*, published by Undark, Lynne Peeples quotes lighting consultant James Benya as saying "...without guiding science, and with the lack of protocols and standards, right now it is the Wild West." Even the DOE has acknowledged the challenge of "documenting and assigning economic value to non-energy benefits."

Some have drawn a parallel between lighting designers and architects specifying human-centric lighting and physicians prescribing medicine or supplements, suggesting that the lighting industry must adopt a stance like the physician's oath: First, do no harm.



Research



Evaluating Science



CS & EML

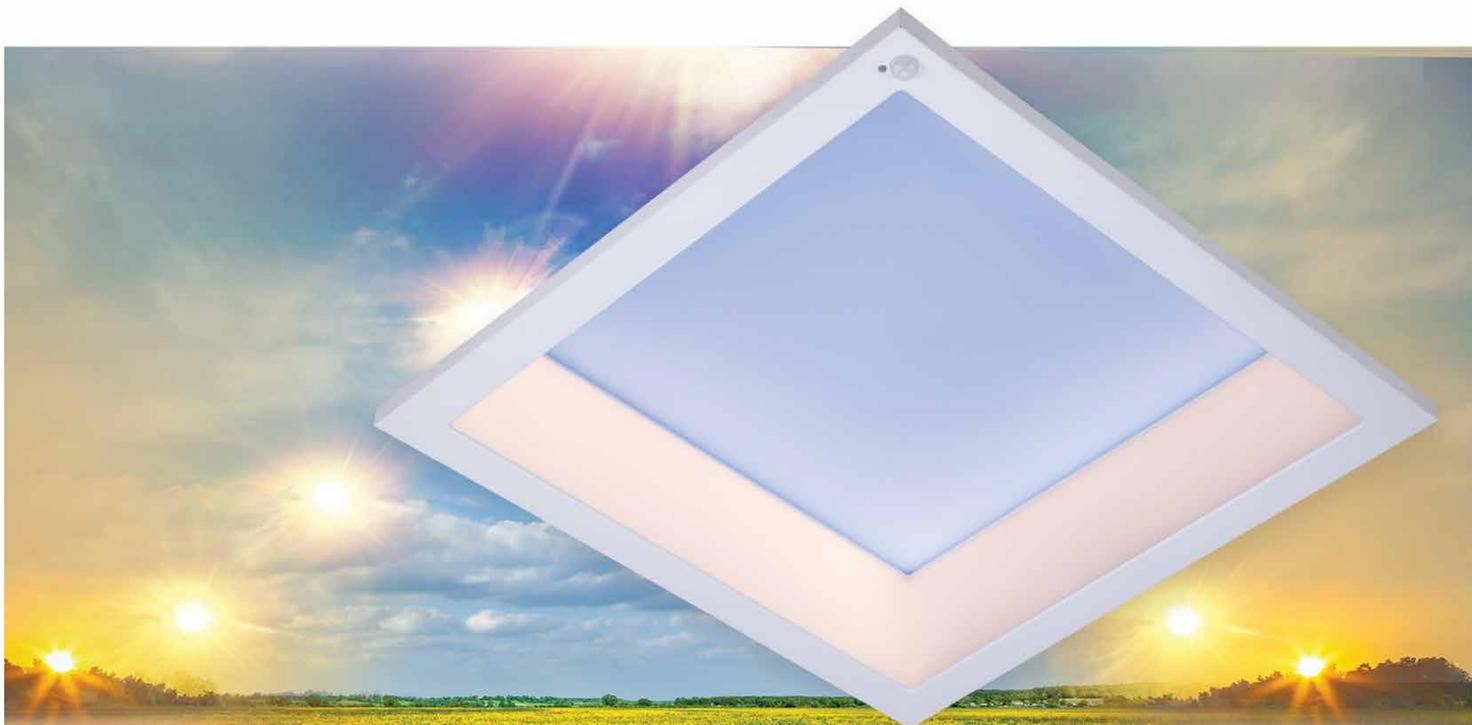
Where To Go From Here

Even critics of “acting now” on human-centric lighting acknowledge the benefits available currently and its compelling promise for the future.

In her article, Peeples also quoted Benya as saying “We know it is going to have a significant benefit for many people,” and the IES appended Ashdown’s article with the recommendation that “we should simply educate designers on the principles of circadian lighting and trust their judgment.”

It’s now mid-2020, and while adoption of human-centric lighting has been creeping forward over the last 10 years, it is accelerating fast today. Some manufacturers are already promoting “spec lighting that’s also circadian friendly.”

Cree Lighting’s Cadian™ Dynamic Lighting Experience was developed for a specialized function – to bring a realistic feeling of the outdoors into spaces where it was not otherwise possible to put windows or a real skylight. The product, along with others from Cree Lighting and competing manufacturers, features the dimming, color tuning and spectral content needed to positively impact human performance and well-being.

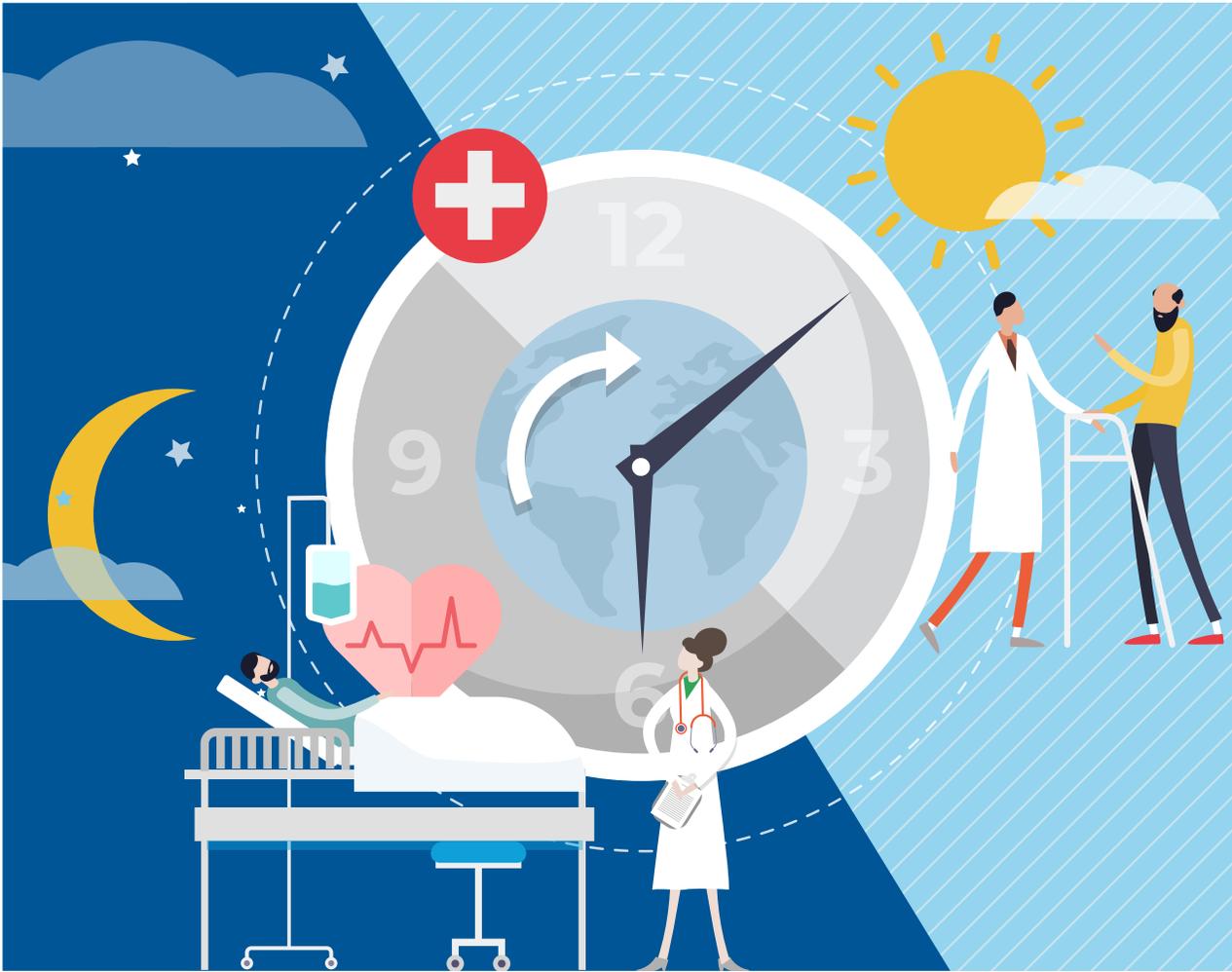




Healthcare and assisted living are among the industries expected to take an early lead in adopting tunable, flexible health-centric lighting, along with education. Many lighting manufacturers already offer health-centric solutions specific to these industries, both for new construction and to retrofit existing facilities.

Most of us are familiar with the consumer categories used to classify buying behavior when embracing a new technology or industry shift: early adopters, early majority, late majority and laggards. There are risks and benefits associated with each, and making the right choice for human-centric lighting will largely depend on your specific goals, priorities and values.

The best advice is to ensure the lighting choices you make today are “future-proof” – flexible, intelligent lighting solutions that are configurable and programmable, so you can apply new research findings as they are validated. Because whether you’re ready now – or not quite yet – lighting optimized for human health, performance and well-being is likely to be the next major game-changer in the lighting industry.



Visit [creelighting.com](https://www.creelighting.com) or contact a Cree Lighting representative to learn more.

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