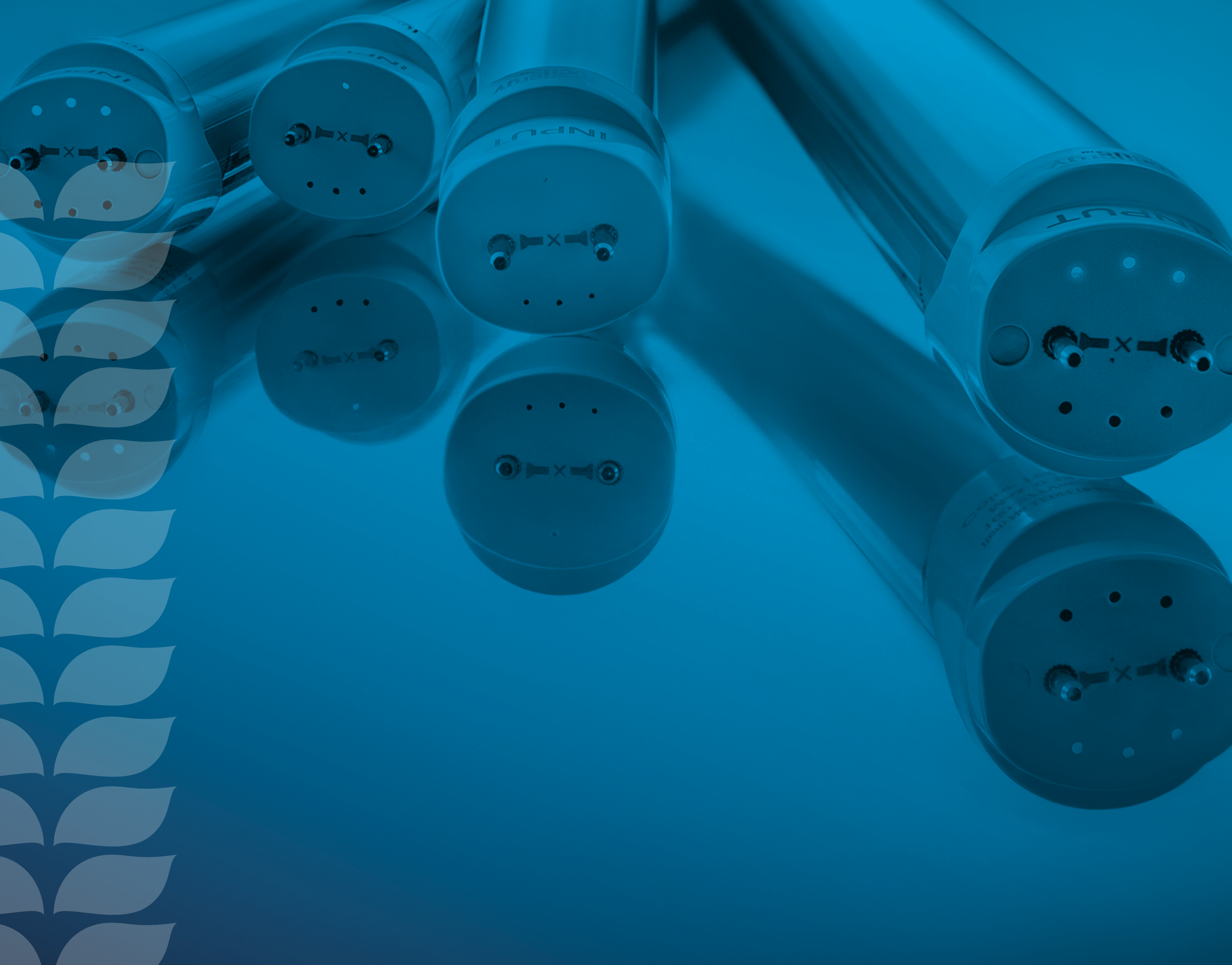
ENLIGHTEN AND INSPIRE

Healthcare Lighting Criteria (HLC)

Standards for high-quality LED lighting in healthcare facilities



Executive summary

LED lighting can dramatically reduce electricity costs in healthcare facilities. However, not all LEDs are created equal. This document describes lighting criteria that are crucial for a healthy environment, as well as product specifications that will ensure a high-quality, reliable lighting solution.

Fundamental precepts of the HLC

1. Do the right thing. It is the responsibility of the lighting solution provider to demonstrate that any solution is the right solution for the healthcare environment, and the expectation that this will require effort above and beyond the general commercial marketplace.

2. The HLC is derived from available technology, and is modified to reflect changes in technology. As such, all technology providers are intrinsic stakeholders in the HLC, with the right and responsibility to bring this knowledge and adoption of technology to the healthcare environment by improving the HLC.

3. The decision makers in healthcare environment have the final say, and may elect to waive or require criteria they believe is in the best interest of their environment. The HLC is not meant to replace the healthcare architects, facilities maintenance, and finance personnel—it is meant to educate and guide them.

Intent

The healthcare environment is a place of wellness. The doctors, nurses, staff, volunteers, visitors and patients are unified in the singular goal of improving quality of life. The individuals that take on these roles have a place of respect in global society, and the clinics that enable them to create wellness are admired for their purpose and vision.
The modern healthcare facility is a specially crafted place tailored to the specialties and specialness of their goals. The impact of the healthcare environment extends beyond the physical hospital and clinic. The trends set by the clinic impact the trends outside the clinic, in our homes and offices. When a clinic creates a program for exercise for their staff, that program finds its way into the office. When the cafeteria menu changes to promote healthy diet, food service providers take note and push the same changes to locations outside the clinic. When the clinic bans smoking on campus and offers smoking cessation courses to aid the transition away from addiction, state legislatures respond by banning smoking in public places.

When the clinics speak, the world listens.

The role lighting plays in wellness—diagnosis, treatment, and recovery—is very important. LED lighting has emerged as a technological breakthrough, providing not just substantial reduction in power consumption, but numerous other benefits in visual acuity, comfort, and happiness. The unfortunate fact is that not all LED products are created the same. As with any new technology, the struggle to redefine standards to take full advantage of the breakthroughs creates confusion. General association with LED as the primary light source is insufficient to achieve the health benefits of the technology. Of equal or greater importance are the technologies that drive the LEDs, the quality of the construction and components, to promote wellness and prevents adverse effects in the healthcare setting. The scope of the Healthcare Lighting Criteria (HLC) is to complement other standards and specifications for performance and wellness with the particular focus on lighting technology that enhances the wellness environment, and the wellness of the environment for the patients and staff of the clinic. It is not meant as a replacement for expertise of lighting designers, architects, or facilities managers that must maintain the clinic, but rather to help educate those who have the responsibility for making decisions and recommending practices that support the goals of the clinic. In many cases, the broad applicability of general standards for performance are insufficient or counter to the needs of the healthcare facility. In these cases, the HLC promotes a higher standard specific for the healthcare space.

Using the HLC effectively

The HLC is divided into two parts:

1. Lighting Design Criteria

These criteria draw upon research that shows positive effects in the healthcare environment, presenting strategies on implementing lighting to achieve similar desired outcomes. When possible, many strategies are presented, such that the history of a building's construction is not a limitation in achieving goals.

2. Lighting Products Specification

These specifications apply to products themselves, and are measurable, verifiable metrics that can be used to ensure quality of the light sources. Specifications are divided into two categories, those that directly affect health and wellness, and those that may indirectly affect wellness. The rationale for the specifications is presented, and in many cases additional optimizations are present. The purpose of optimizations is to allow stakeholders to easily adopt more aggressive specifications that reflect their need. Optimizations are also intended for future introduction of a "wellness grade" product scoring system.

1. Lighting design criteria

Circadian rhythm

As light enters the eye, a variety of photoreceptors in the retina transmit signals to different parts of the brain. Rods and cones facilitate visual processing, while other photoreceptors known as intrinsically photosensitive retinal ganglion cells (ipRGCs) function to synchronize non-visual physiological processes. One ipRGC in particular, the melanopsin receptor, has a peak sensitivity to light in the blue range, and is pivotal in regulating our Circadian Rhythms via suppression of melatonin when activated.

The light needed for this Circadian Photoentrainment should have enough intensity within the blue range to effectively suppress melatonin during desired times, which can be measured by the melanopic lux (m-lux), or melanopic to photopic lux ratio (m/p). The photopic lux measures the contribution of the light source to photopic vision, or visual processing via cones, while the melanopic lux measures the contribution of the light source to melatonin suppression via the ipRGCs. The m/p ratio is a practical method to determine if any light source is providing enough light needed for daytime conditions when an awake state is appropriate. When the presence of melatonin in our system is desirable, to prepare our bodies for productive sleep, light should be avoided, especially light with a substantial m/p ratio.

It is important to consider the level of m-lux for the tasks at hand. For example, lights should have enough melatonin suppression for locations that are associated with wakeful activities, such as offices, operating rooms, and work stations in hospitals. Meanwhile, patient rooms, homes, and spaces where alertness poses an obstacle to healthy sleep should avoid lights with high m/p ratios, or at least allow for control to reduce the light levels so as to maintain a healthy cycle. [International Well Building Institute. “Light” The WELL Building Standard v1. February 2016.]

At this time, the exact dosage and timing of m-lux levels for proper Circadian Photoentrainment is not well-enough understood that it can be summarized in easy to measure metrics. Preliminary research indicates that mimicking sun-cycle conditions has a positive impact on immediate productivity, as well as long-term regulation of sleep/wake cycles. These impacts along with other hormonal regulation via light are thought to effect other physiological and psychological processes such as healthy weight, growth, mood, and overall quality of life. [Roberts, Joan E. “Light and Immunomodulation” Annals New York Academy of Sciences. 2000].

1. Lighting design criteria

Circadian rhythm

Strategies for providing the right amount of m-lux

Increasing m-lux to promote alertness in staff and patients
Higher brightness corresponds to increased m-lux. While proper levels of light are desired for work-flow, energy conservation techniques promote aggressively reducing light levels. A balance must be struck that light levels are not too dim, for both the task at hand and sufficient m-lux. When considering the right amount of light for a space, consult the recommendations from the IES Lighting Handbook. These are frequently a range, and studies are showing that full-spectrum LED lighting has better visual acuity than the broken spectrum lighting produces by fluorescent sources. [Brown et al.] As such, providing light levels from LED sources in the low to middle portion of the recommended ranges often yields the right amount of light.

One method of energy savings is to default the light in a space to a fraction of the recommended level and allow a user to override. For example, an office equipped with an occupancy sensor can be equipped to automatically bring lighting to 50% brightness when it detects someone entering the room, while pressing the wall switch can bring it to full brightness. In situations such as these, it is important to educate the users of their ability to adjust brightness. While a reduced lighting level that is still sufficient to perform necessary tasks is a good scenario, if productivity or comfort are sacrificed because the user does not realize the override exists, the loss is much greater than any energy savings gain.

Lowering m-lux to promote sleep in patients
Brightness reduction: The simplest method of reducing m-lux is reducing brightness. Turning the lights off or dimming lights down takes advantage of the m/p ratio. In patient rooms and recovery areas, when room lighting supports multiple switches, separate the lighting that illuminates the patient from lighting that illuminates the periphery of the room, equipment, or pathways. The use of indirect lighting in soffits, under cabinets, or similar locations provide a low level of glare-free light. Consider simple solutions for highlighting this in the controls, such as using switches with a sun for daytime lighting and moon for nighttime lighting.

When the room does not readily support multiple switches, a good solution is to implement a policy to keep room installed lighting off and use other methods for tasks. Add additional plug-in luminaires as needed to illuminate critical spaces while the room lighting is off, or provide easily accessible flashlights. New digital lighting controls can expand the inherent capabilities of the legacy wiring in a room. These usually add a form of communication, most commonly wireless but sometimes wired or communication over powerlines, to signal to the lamps. Be aware that the additional wireless signals can cause interference with other equipment.

1. Lighting design criteria

Improving patient outcomes

Recovery and mortality

Research has shown that patient outcomes can be improved and hospitalization times shortened when the patient room has increased amounts of daylight from a window. [Choi et al. "Study of the Relationship between Patients' Recovery Time and Indoor Daylight Environment of Patient Rooms in Healthcare Facilities" Texas A&M University 2004]. Studies also show than when the ambiance of the recovery space, including lighting that mimics a dawn-to-dusk pattern, similarly improves comfort and recovery. [Jennings et al.]

Reduction of errors

Improving the workspace for staff, to reduce the risk of errors, is correlated to improved patient outcome. This may include providing higher brightness for staffers as necessary, such as for older adults and those with vision conditions.

"The work environment for nurses and physicians in hospitals is stressful. They are required to perform a range of complex tasks: charting, filling prescriptions, administering medication, and performing other critical patient-care tasks. Inadequate lighting and a chaotic environment are likely to compound the burden of stress and lead to errors. However, very few studies have focused specifically on the impact of different types of lighting conditions on staff and work performance in hospitals.

One study examined the effect of different illumination levels on pharmacists' prescription-dispensing error rate (Buchanan, Barker, Gibson, Jiang & Pearson, 1991). They found that error rates were reduced when work-surface light levels were evaluated (450 lux; 1,100 lux; 1,500 lux). Medication-dispensing error rates were significantly lower (2.6%) at an illumination level of 1,500 lux (highest level) compared to an error rate of 3.8% at 450 lux. This is consistent with findings from other settings that show that task performance improves with increased light levels." [Source: Anjali Joseph, Ph.D. "The impact of Light on Outcomes in Healthcare Settings" The Center for Health Design.]

Improved Immune Response

In additional to eye-brain hormonal pathways, direct immune system response to light exposure on skin has been demonstrated. Specifically, regulation of circadian rhythms is associated with improved immune function. [Source: Joan E. Roberts, Ph.D. "Light and Immunomodulation" Annals New York Academy of Sciences, pp 435-445]

2. Lighting product specifications
Directly related to health and wellness

Flicker

- <5% flicker from 0 to 2000Hz, as calculated by A-B/(A+B). <15% flicker from 2kHz to 1000kHz.
- Flicker is modulation in light amplitude over time, including on/off blinking as well as partial changes in intensity. Flicker is very often substropic, meaning it has frequency that is not visible to the eye, but can still cause eye strain, headache, and has risk of inducing seizure in people with epilepsy. Flicker may also interfere with electronic equipment, such introducing artifacts in video to conferencing equipment, or devices like barcode scanners. [IEEE P1789]

Dimming

- Shall be 0-10V IEC 60929/ANSI C137.1 standards compliant (no phase-cut dimming).
- Optimization 1: Tabulation that compares light level, power consumption, and visual perception

Prohibitions

• **Hazardous materials:** manufacturer must declare that no hazardous materials are present, and assume responsibility for removal and replacement of products if a reasonable level of understanding existed at the time of sale that hazardous materials were in the product. This includes through contact or standard use (outgassing, etc.) and into waste stream at time of disposal.
Exception: When a manufacturer takes steps to "season" a product before installation, to remove potential hazardous materials.

• **Ultraviolet (UV) spectra:** Defined as wavelengths <400 nm, intentional emission of UV for general lighting applications is prohibited.

• Mercury-added products are prohibited, due to the risk of mercury contamination in use and into the waste stream.

• Excess/unnecessary components that produce additional or unnecessary waste, both material waste and consumption waste, are prohibited.

• LED lamps that operate on fluorescent ballasts are included in this, as continual ballast replacement is an unnecessary source of waste.
Exception: Products that allow eventual removal of the ballast, so-called dual mode, are allowed if the manufacturer can meet the following criteria:

1. *The manufacturer can clearly show that HLC criteria are met in both modes of operation, and that the product is compatible with a future change in the wiring.*
2. *Instructions that indicate how the ballast removal should take place are clearly available on the product or fixture. Do not assume that a separate instruction will be available many years after the retrofit.*

2. Lighting product specifications
Indirectly related to health and wellness

AC input voltage: 100–277 VAC, 50/60Hz auto-ranging
Exception: Workspace lighting or portable lighting that includes a standardized cord connector.

Power factor (PF) >0.9
Power factor is a measure of consumption efficiency, with 1 being a perfect consumer. Poor power factor may cause an issue with ampacity limits in wiring, and is typically penalized by utilities in billing.
• Optimized 1: PF > 0.95 @ 120VAC and >0.90 @ 277VAC
• Optimized 2: PF > 0.95 for all voltages

Electro-magnetic interference (EMI) FCC title 47 part 15 class B or part 18 or CISPR 15.
Manufacturer shall provide third party verification of compliance from an accredited source. Electromagnetic interference (EMI) and Radio Frequency Interference can cause disruption to electronic devices and wireless communication. Most electronic devices, including medical equipment and LED lighting, both produce EMI and can be affected by EMI. Standardized testing often includes ensuring primary function is not disrupted by the influence of outside EMI, while FCC or CISPR enforces reducing the EMI produced by a light. However, these limits may not necessarily be indicative of the high density of electronic equipment found in areas of a clinic hospital.
• Optimization 1: 6dB below FCC
• Optimization 2: Demonstrate FCC or CISPR for full fixture equivalent (or total in-room solution).

Intentional radiators
Manufacturer shall provide transmission power, including peak power, maximum duty cycle, band of operation, average and maximum sustained output, and receiver sensitivity and bandwidth. While EMI is a form of undesired electromagnetic interference, often a byproduct of the normal function of the device, many items are intentional radiators. Wireless communications devices are the most common, and typically utilize unlicensed bands to operate. These bands can become congested as the number of devices increases, causing information collision and interference with normal operation. Signal in one band may interfere with devices in another band if the device does not adequately filter off undesired signals.

Color rendering (CRI or TM-30) >80

Color temperature
Color temperature is defined by the building architects, and their judgment on the proper color cast of a space. Reference the section regarding the effects of lighting on healing and mortality for additional information.
Melanopic lux: Report ratio of melanopic to photopic lux. For products that support tunable CCTs, this report shall include manufacturer recommended settings and associate m-lux, or at all of the supported CCTs in the following list: 3000K, 3500K, 4000K, 5000K, 6000K.

2. Lighting product specifications
Indirectly related to health and wellness

Total harmonic distortion THD < 20%, with no more than 19% in any one harmonic.
Total harmonic distortion, specifically load current (ATHD), is a form of electronic pollution. Specifically, it is a ratio of all so-called harmonic currents to the fundamental current, the latter being the current consumed by a device at the frequency of the electrical grid. Fundamental current is directly proportional to power. Harmonic current may or may not be directly related to power, and in many cases is fixed and can be treated like overhead.

In great amounts it can distort mains voltage, which can in turn cause malfunction in equipment that uses the line voltage for cadence as well as power. Variable Frequency Drive (VFD) motors, another technology lauded for its positive energy conservation, are particularly susceptible to fifth harmonic currents and are often heavily filtered to protect them. While medical and industrial equipment typically undergoes some form of line quality testing, the standards are not necessarily indicative of the high density of electronic equipment found in areas of a clinic hospital.

Note that THD is strongly related to power, and does not specifically address frequency content. More efficient lights that use less power, or lights that can reduce power through dimming, will necessarily have higher THD. The extreme is a switched off light that consumes 0W, making THD infinite. A light that consumes 28W at 10% THD has the equivalent harmonic current as a 14W, 20% THD light, making the latter a preferred solution due to its reduced power consumption. As such, consider using a quality metric of THD x power to compare solutions to legacy and each other.

- Optimized 1: <15%, with no more than 14% in any one harmonic.
- Optimized 2: < 0%, with no more than 9% in any one harmonic.

Light level and efficacy
The goal of light level and efficacy specifications are to ensure the right level of light, with the minimum level of energy consumption. As energy consumption is related to fuel consumption and CO^2 emissions, along with the impact of those on our environment, promoting efficient lighting extends beyond the utility bill.

2x2 and 2x4' general illumination: 100 lm/W from recessed, surface mount, or pendant mount fixture. In the case of retrofit lighting, the light source will have to exceed this final specification to overcome losses in the fixture. IES LM-79 data shall be available to justify the claim.
- Optimization 1: 110lm/W
- Optimization 2: 120lm/W

Downlights, 4"–14": 70lm/W from can. In the case of retrofit lighting, the light source will have to exceed this final specification to overcome losses in the fixture.
- Optimization 1: >85 lm/W
- Optimization 1: >100 lm/W

Non-listed category: Manufacturer shall provide a cost analysis justifying the performance.

About Energy Focus

Energy Focus is an industry-leading innovator of energy-efficient LED lighting technology. As the creator of the only flicker-free LED products available, our lighting solutions provide significant and measurable benefits over conventional and fluorescent lighting, including extensive energy savings, safety and health benefits, and improved aesthetics.

As a long-standing partner with the U.S. government, Energy Focus has a proud history delivering energy-efficient LED products to the U.S. Navy. Every unit we ship is subject to rigorous testing in the most adverse conditions possible, ensuring unparalleled quality and reliability. Our family of customers and partners include national, state and local U.S. government agencies as well as Fortune 500 companies across education, healthcare, retail and manufacturing industries. Energy Focus is headquartered in Solon, Ohio.

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